HOW TO SURVIVE EXTREME WEATHER

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANS…TORY SPACE

"IT'D BE COOL IF WE WERE SOME ALIEN SIMULATION"
NEIL DEGRASSE TYSON SPEAKS

VENUS: EARTH'S EVIL TWIN

What can this toxic planet teach us about our own?

EVERYDAY CARS

WORLD'S MOST POISONOUS PLANTS

HYDRO FOILS

PERSONAL PLANES

HIGH-VOLTAGE ⚡ ECO-FRIENDLY

ELECTRIC VEHICLES

HOW SUPERCHARGED BATTERY TECH IS TRANSFORMING TRAVEL

PASSENGER FLIGHTS

POWER BOATS

SUPERCARS

THE SECRETS OF SNAKES

The lives of these slithering serpents revealed

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INSIDE THE HTC VIVE

How does this VR headset track your every move?

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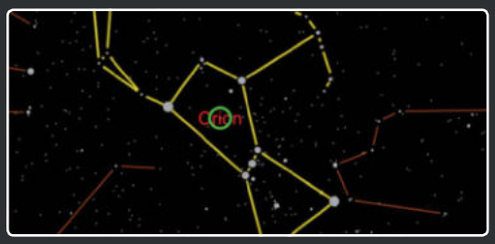

Images of all **88 constellations** of the heavens

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ISSUE 90

WELCOME

The magazine that feeds minds!

"Tornadoes can whip up winds exceeding speeds of 400 kilometres per hour"

Surviving extreme weather, page 48

Meet the team...

Dave
Editor-in-Chief
I love getting out on my mountain bike in the summer, and I really enjoyed reading all about the poisonous plants that can be found in the countryside. Now I know which ones to avoid!

Katy
Research Editor
Don't bother telling a snake that its eyes are bigger than its stomach – their jaws are specially built to gulp down their prey in one go! Find out more about life as a legless reptile on page 26.

Jack
Senior Staff Writer
Electric vehicles are the future. Head over to page 14 to see some incredible new battery-based designs for land, sea and air leading the charge as the world of transportation turns an electric blue.

Duncan
Senior Art Editor
I'm massively excited about the HTC Vive, having got addicted to the amazing 3D painting tools where you can paint with lava, sparks and fire! Head over to page 44 to see how it works.

FOLLOW US... How It Works magazine @HowItWorksmag

I was lucky enough to take a ride in a Tesla Model S last year, and quickly became an electric car convert. If only I could afford the hefty price! That said, many companies are making electric car tech more affordable, and by 2022 it is predicted that plug-in vehicles will be cheaper to own than conventional gasoline guzzlers. Just think how peaceful the roads of tomorrow will be with e-cars quietly zooming by!

Also in this issue, our special feature on extreme weather survival reveals the science and tech that will keep you safe during a storm. Meanwhile in the technology section, we look to the future of education and imagine what the classroom of 2050 could look like.

Can you think of a body part that begins with x, y or z? Compiling the list wasn't easy, but we've managed to take an alphabetical anatomical journey in the science section. Hopefully this edition of **How It Works** will exercise your zygomaticus major muscle (see page 63!)

Enjoy the issue!

Jackie **Jackie Snowden**
Deputy Editor

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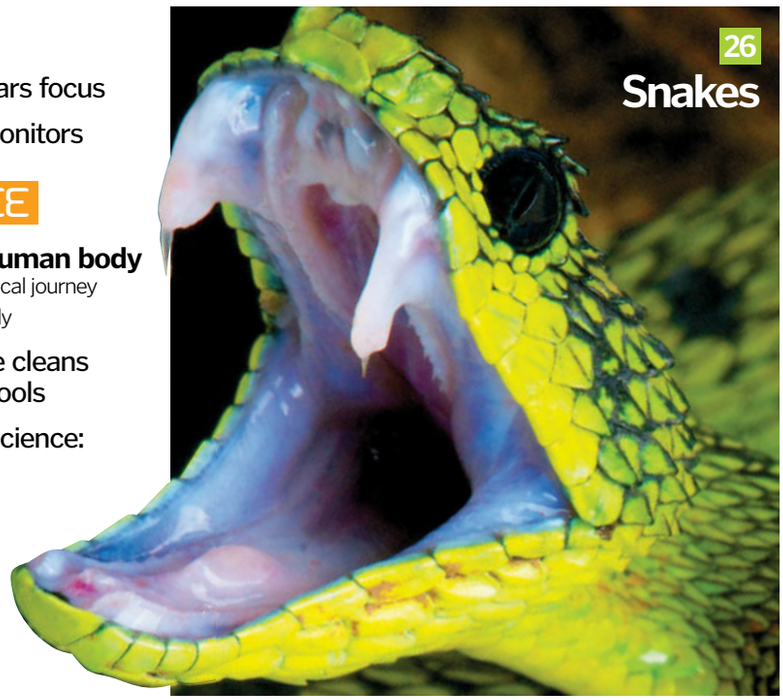
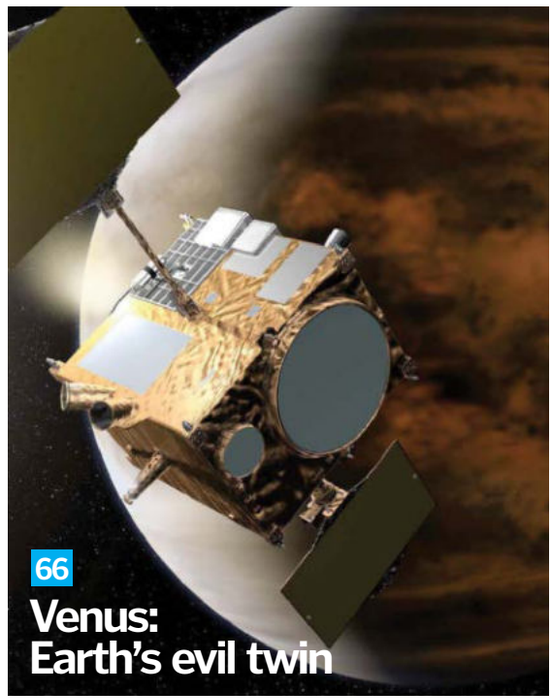


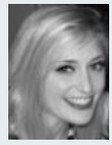


Meet the experts...

Edoardo Albert
Edoardo Albert has had a life-long fascination with England, its history and mythology. This month he explains how to forge the perfect sword over on page 76.

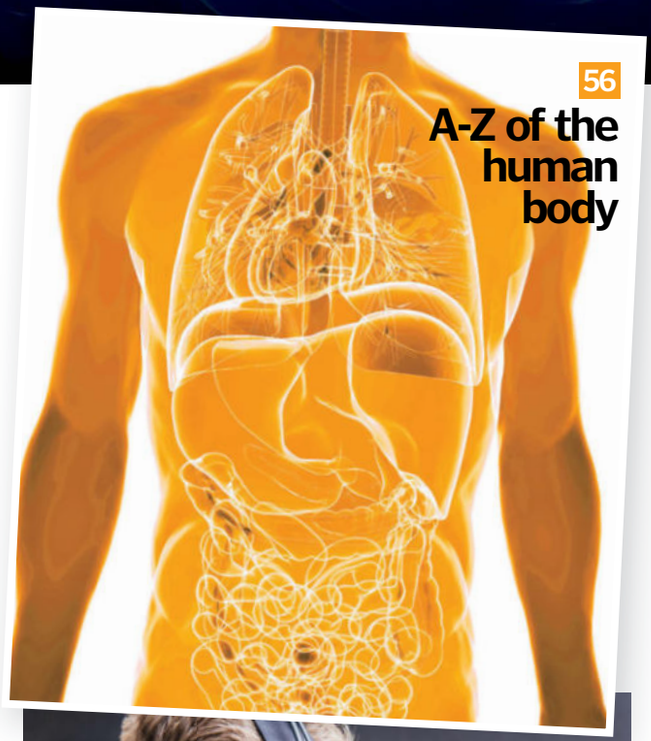
Laura Mears
Laura takes us on an anatomic adventure as we take an alphabetical tour of the human body, from alveoli to the zygomaticus major muscle. She also explains hydraulics in 60 seconds.

Jo Stass
How It Works alumnus Jo couldn't bear to leave us completely! In a special feature on surviving extreme weather, she explores the science and tech that keeps us safe when disaster strikes.

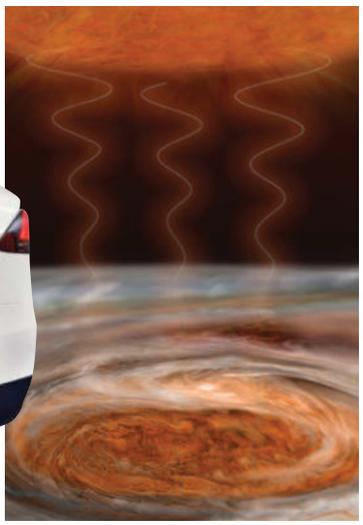


Ella Carter
Check out page 26 for Ella's feature on the secret lives of snakes. She delves inside the belly of the beast to reveal the anatomy of these slithering serpents.

Stephen Ashby
Steve explains the tech that could transform schools as we take a look at the future of classrooms. Anyone up for a virtual reality field trip to Mars?



REGULARS



HOW IT WORKS **Reader Survey**

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We love making **How It Works** and we hope you love reading it too. But we want to keep making it even better, so we're asking for your help. By answering just a few questions, you could be selected to join our latest **How It Works** panel. We're so excited to hear what you have to say and can't wait to learn more about you.

Jackie

Jackie Snowden
Deputy Editor

HOW IT WORKS

Three changes you asked for in 2015

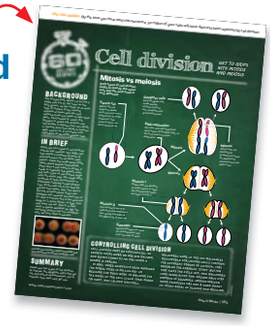
Last year we used your input to make some fantastic improvements, including…

1 Reviews of the latest books

After discovering you were all keen readers we started reviewing our favourite new releases.

2 60 second science

An all-new, regular feature that explains key scienctific in principles in under a minute.



3 "Day in the life" interviews

Readers can now get a behind-the-scenes look at exciting jobs in the world of science and tech.

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Jupiter's Great Spot is red hot

New studies suggest that the gas giant's spinning megastorm is a huge heat source

Jupiter's Great Red Spot is undoubtedly the planet's defining aesthetic feature. This gigantic, perpetual storm is two-to-three times wider than Earth, and its origins and behaviour have been the subject of studies since its discovery over 350 years ago.

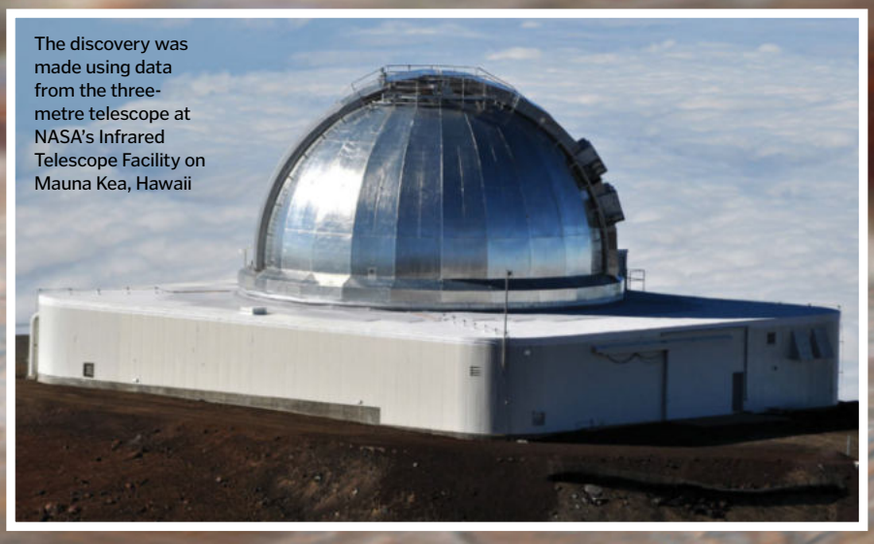
A group of researchers from Boston University's Center for Space Physics have recently suggested that the storm may in fact be responsible for heating Jupiter's upper atmosphere. Surprisingly, temperatures in Jupiter's uppermost layers are similar to those found on Earth. While our atmospheric temperatures are affected by solar heating, Jupiter orbits five times further from the Sun than Earth does, so there must be other sources.

Using data from an infrared telescope and the SpeX spectrometer at NASA's Infrared Telescope Facility in Hawaii, the team mapped Jupiter's atmospheric temperature variations. "We could see almost immediately that our maximum temperatures at high altitudes were above the Great Red Spot," explained James O'Donoghue, lead author of the research paper.

The team theorise that the storm produces both gravity waves and acoustic waves, and when the two types collide in the upper atmosphere they give off heat.

This explains why the areas above the storm are hundreds of degrees hotter than what would be expected if Jupiter was heated only by solar energy.

The winds of the Great Red Spot can reach 650 kilometres per hour, around twice the speed of Earth's most powerful hurricanes



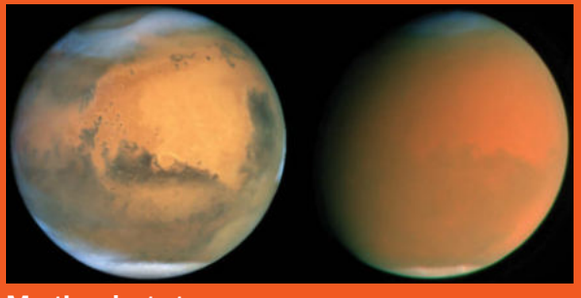
The discovery was made using data from the three-metre telescope at NASA's Infrared Telescope Facility on Mauna Kea, Hawaii

"This gigantic, perpetual storm is two-to-three times wider than Earth"

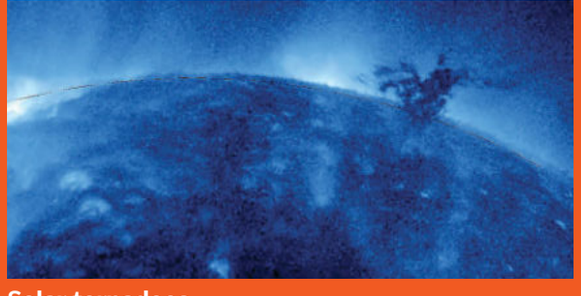
Extreme cosmic weather occurs across the Solar System...

Saturn's Great White Spots
These huge storms appear periodically in Saturn's northern hemisphere during the summer. They start as spots, but the storm's 'tail' can extend so far that it goes all the way around the planet.

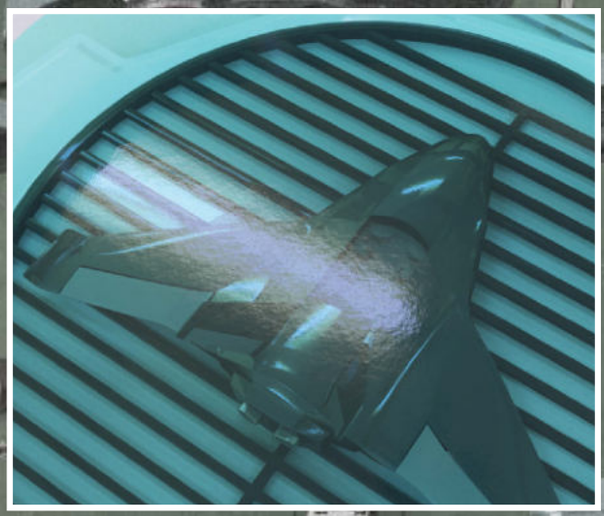
Neptune's disappearing Great Dark Spot
Spotted during the flyby of Voyager 2 in 1989, this Earth-sized anticyclone was clocked with winds of up to 2,400km/h. The storm had dissipated by the time Hubble looked at it in 1994.



Martian dust storms
Occasionally, Mars' dust storms manage to engulf the entire planet. These events can block out the Sun, which causes problems for the solar-powered rovers we send to the Red Planet.



Solar tornadoes
Huge twisters of superheated plasma sometimes swirl on the surface of the Sun, stretched and pulled by intense magnetic forces, at speeds of up to 300,000km/h.



TALKING POINT

COULD WE 'GROW' DRONES?

BAE Systems' futuristic concept combines 3D printing and chemical reactions to revolutionise operations

Scientists and engineers from BAE Systems and the University of Glasgow have developed some innovative designs that could dramatically change the way unmanned aerial vehicles (UAVs) are manufactured.

A theoretical machine called a 'chemputer' could use advanced chemical processes to build up military aircraft and their components from the molecular level. While a 3D printer assembles the physical parts of the machine, the chemputer would help speed up chemical reactions. Drones could be designed and effectively grown to suit the specific mission they will be used for. This unique approach means that custom UAVs could be produced in a matter of weeks, rather than through years of research and development. Such technology would offer a significant military advantage, allowing bespoke UAVs to be created quickly to respond to changing threats.

"This is a very exciting time in the development of chemistry" says Lee Cronin, professor at the University of Glasgow and Founding Scientific Director at Cronin Group PLC – the company developing the chemputer. "We have been developing routes to digitise synthetic and materials chemistry, and at some point in the future hope to assemble complex objects in a machine from the bottom up, or with minimal human assistance."

This concept might seem like the stuff of science fiction, but considering that we already use 3D printing to produce warplane components or drones, the idea isn't that absurd. "Creating small aircraft would be very challenging" adds Cronin, "but I'm confident that creative thinking and convergent digital technologies will eventually lead to the digital programming of complex chemical and material systems."

NEWS BY NUMBERS

400 years

The estimated age of Greenland sharks, making them the longest-living vertebrates

200

The number of meteors per hour in August's Perseid shower, double the usual rate

10x

How much more efficient a bionic leaf is compared to natural photosynthesis

43.03 seconds

The new 400-metre world record set by South African Wayde van Niekerk at the Rio Olympics

Farming on water will help free up arable agricultural space and allow over-farmed fields to recover

Floating farms

A new agricultural innovation could be the key to feeding rising world populations

Developers are planning to build a floating dairy farm off the coast of Rotterdam in The Netherlands. Construction of the floating farm is due to begin later this year, and when completed, it will be home to up to 60 cows. The dairy will be both a farm and a high-tech laboratory, where researchers can test out improved food production, waste recycling and water treatment processes. It is hoped that this concept could inspire similar projects that increase food production while not using up hectares of land.

The Armada Portrait has influenced many portrayals of Elizabeth I, both in theatre and on screen

Elizabeth I portrait is public property

The famous painting has been bought for Britain

The Armada Portrait is one of the most iconic images from the English Renaissance, commemorating the failed Spanish invasion of 1588. Following a popular appeal by the Royal Museums Greenwich Art Fund, 8,000 donations were made by members of the public and various trusts, including a £7.4 million grant from the Heritage Lottery Fund. The portrait is now publicly owned and will hang in the Queen's House from October. Fittingly, this site was the location of the original Greenwich Palace, where Queen Elizabeth I was born.

A superbug slayer may have been lurking right under our noses

New antibiotic found in nose

Bacteria from our own bodies could protect us from superbugs

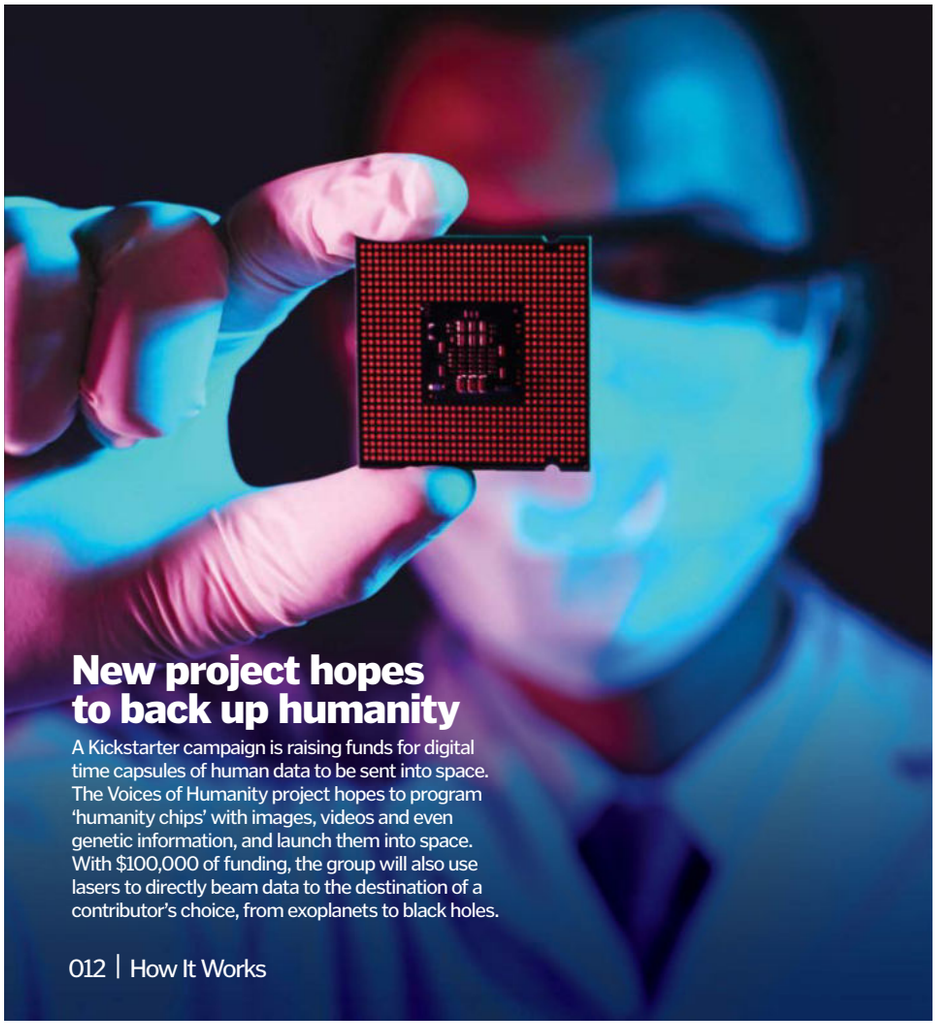
Overuse of antibiotics has led to some harmful bacterial species becoming immune to even our 'last-resort' medicines. The search for new superbug-slaying substances is incredibly important, but scientists are finding potential new antibiotics in some surprising places. One of the many bacteria within our nostrils, Staphylococcus lugdunensis, has recently been found to produce a compound, called lugdunin, that destroys methicillin-resistant Staphylococcus aureus (MRSA).

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Primates like to get tipsy

New research has found that when seeking out nectar, primates prefer the strong stuff. In an experiment with aye-ayes and slow lorises in captivity, researchers offered a selection of sugary water mixtures (similar to nectar) containing varying amounts of alcohol. The primates drank around twice as much of the boozier blends compared to the weaker solutions. Scientists believe that this penchant for booze is an advantage in the wild, as alcoholic vapours help animals to find edible flowers and fruits in the wild.

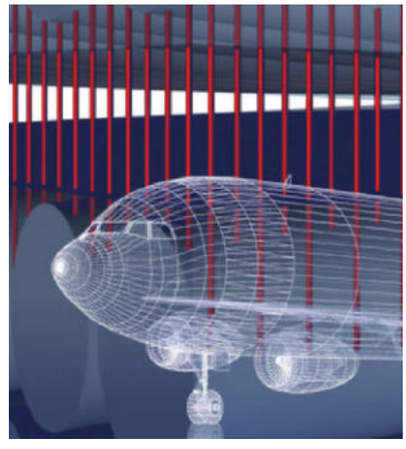


New project hopes to back up humanity

A Kickstarter campaign is raising funds for digital time capsules of human data to be sent into space. The Voices of Humanity project hopes to program 'humanity chips' with images, videos and even genetic information, and launch them into space. With $100,000 of funding, the group will also use lasers to directly beam data to the destination of a contributor's choice, from exoplanets to black holes.

Carbon nanotube stitches make planes stronger

Aerospace engineers from the Massachusetts Institute of Technology have designed a method of bonding aircraft frames. Carbon nanotubes incorporated into a glue-like substance hold sections of the fuselage together, making it 30 per cent stronger and more resistant to damage.

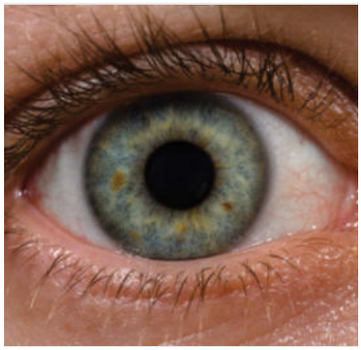


Grass is a renewable energy source

Your garden could become a cheap and eco-friendly source of renewable energy in the future. Experts from Cardiff University have discovered that by using sunlight and a cheap catalyst, hydrogen can be produced from grass. The process is called photocatalysis, and works by using solar energy to activate the chemical catalyst, which helps to convert the plants' cellulose into hydrogen and water.

An asteroid created the Moon's eye

An asteroid that smashed into the lunar surface 3.8 billion years ago, forming the Mare Imbrium crater – the Man in the Moon's right eye – was much larger than previously thought. A new study has found that the space rock could have been over 240 kilometres in diameter, large enough to potentially be classed as a protoplanet rather than an asteroid.

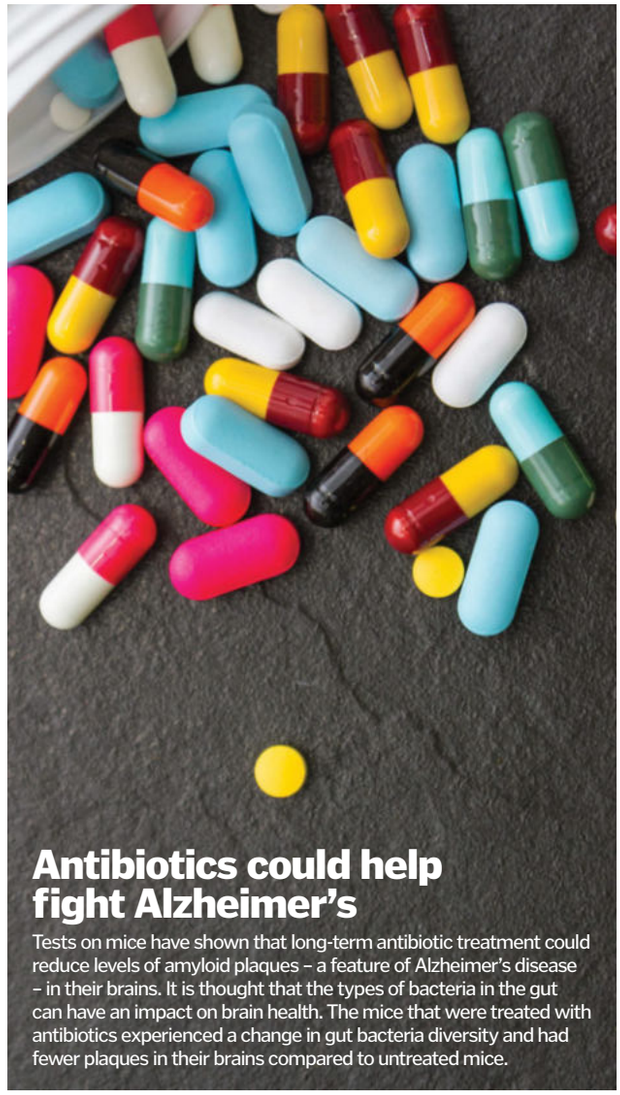


The human eye can detect a single photon

After 70 years of research into the limits of human vision, a new study has found that our eyes can detect a single photon – the fundamental particle of light. Volunteers sat in a dark room, before single photons were fired into their eyes. The participants managed to identify photons correctly more often than if they were just guessing at random.

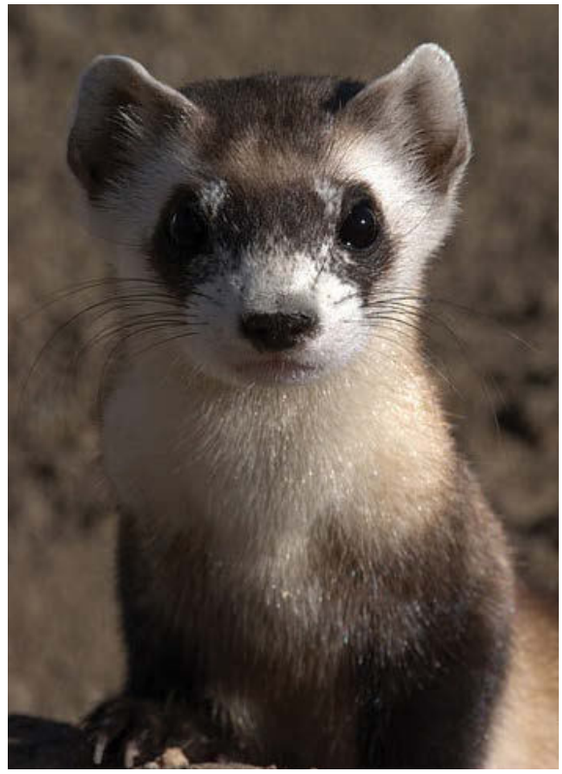
Australia is on the move

Australia is changing its latitude and longitude to fix a one-metre difference between its local and global coordinates. Due to tectonic activity, Oz moves roughly seven centimetres north every year. This means that satellite data and local map data don't match up, creating problems for systems that rely on accurate location information, such as driverless cars.



Antibiotics could help fight Alzheimer's

Tests on mice have shown that long-term antibiotic treatment could reduce levels of amyloid plaques – a feature of Alzheimer's disease – in their brains. It is thought that the types of bacteria in the gut can have an impact on brain health. The mice that were treated with antibiotics experienced a change in gut bacteria diversity and had fewer plaques in their brains compared to untreated mice.



Peanut butter helps to prevent plague

Sneaking a vaccine into pellets of peanut butter could save North America's endangered black-footed ferret population. A devastating disease called sylvatic plague. affects their main prey, prairie dogs, leaving the ferrets with no food. The vaccine against sylvatic plague is difficult to administer to entire colonies of prairie dogs via injection. Instead, scientists tested a new approach by incorporating it into food pellets. Given a choice of pellets hidden in blueberries, sweet potatoes or peanut butter, the latter was found to be the prairie dogs' favourite.

GM silk is tougher than Kevlar

'Dragon Silk' is a genetically engineered product combining the strength and elasticity of spider silk with the ease of production of silkworm silk. Scientists isolated the sections of spider DNA that code for silk proteins, and inserted this genetic information into silkworms. The modified fibres that these GM silkworms produce is one of the toughest in the world, and the US military are investigating how it could be used for soldiers' body armour.

HIGH-VOLTAGE ECO-FRIENDLY

ELECTRIC VEHICLES

FROM PLUG-IN PLANES TO BATTERY-POWERED BOATS, WE EXPLAIN WHY THE FUTURE IS VERY BRIGHT

Aero tunnels
Air flows through the body of the FFZero1, cooling the battery and reducing drag.

Petrol and diesel cars may still dominate the roads, but their days are numbered. A recent study by the Massachusetts Institute of Technology (MIT) found that current electric cars could feasibly be used for 87 per cent of daily car journeys in the US. That figure could rise to 98 per cent by 2020.

One hurdle in the widespread adoption of electric cars has been 'range anxiety' – drivers' concerns about running out of juice on a journey. While petrol stations are conveniently located across national road networks, the electric charging station infrastructure is still being developed. That said, charging points are becoming increasingly common. In Japan, for example, they now outnumber petrol stations.

Attitudes towards electric vehicles have changed quite considerably over the last few years. Not that long ago, electric cars were met with cynicism, and their hefty price tags drove customers away. Thanks to improvements in battery capacity, recharging times, performance and price, the current generation of electric cars are starting to convert critics. Plug-in cars will soon give internal combustion engine models a run for their money. By 2022 experts predict that owning a battery-powered vehicle will be cheaper than owning a conventional car.

As well as advancements on the road, electric vehicles are also taking to the seas and skies. Electric boats are among the oldest methods of electric travel, having enjoyed several decades of popularity from the late 19th to the early 20th century before petrol-powered outboard motors superseded them. Now, the global drive for renewable sources is bringing electric boats back. Steps towards electric air travel are also being made, with Airbus and NASA among the organisations developing and testing battery-powered planes. The lessons learned from these prototypes, combined with continued progress in battery technology, could soon make commercial electric flight a reality.

Electric vehicles do not release any emissions. If the US were to act on the MIT study and replace 87 per cent of its cars with electric vehicles, it would reduce the national demand for petrol by 61 per cent. However, production processes and the generation of electricity required to charge these cars, boats and planes cannot claim to be emission-free. That said, as many countries continue to increase their use of renewable energy sources, electric vehicles will become even cleaner.

Electric power
A dozen electric motors combine to deliver 2,200 horsepower to the Cigarette AMG Electric Drive.

"In Japan, charging points now outnumber petrol stations"

Tesla Model 3

Take a look at the upcoming release set to make electric cars affordable

Over 373,000 Model 3s have been pre-ordered, with the first deliveries expected by late 2017

Futuristic dashboard
The minimalist interior features a large touchscreen interface rather than the usual button-covered dashboard

Autopilot
The Model 3 will include Tesla's Autopilot as standard. This system features autosteer, lane change and autopark capabilities.

Long range
The Model 3 will be able to travel up to 350 kilometres on a single charge.

High performance
It will be able to hit 100 kilometres per hour in just under six seconds.

Extra space
With no internal combustion engine, there's room at the front of the car for an additional boot.

Supercharged
Tesla owners can charge their vehicles in mere minutes at the company's supercharging stations.

Price
Tesla will make the Model 3 its most affordable car yet, with a price tag of $35,000 (approximately £27,000).

Upgrade your ride
Like the Models S and X, the Model 3 will have an optional 'Ludicrous Speed' mode that can boost the car's acceleration.

"3D printing enables ideas to go from idea to sketch to prototype as quickly as possible"

Tesla vs Faraday Future

The electric car behemoth Tesla goes head-to-head with newcomer Faraday Future in an all-electric face-off

Named after the acclaimed physicist Nikola Tesla, Tesla Motors was founded in 2003 and emerged out of Silicon Valley with a mission to mass market advanced electric cars. The company's first release was the Roadster, which became the first production car to use lithium-ion batteries and showed critics that electric cars could be the future. In 2012 came Tesla's sophomore effort – the Model S. It was the first premium electric saloon, and it was quickly followed by the Model X, a sport utility vehicle. Tesla is now working on the Model 3, which will roll off the production line in late 2017. It aims to be the most affordable Tesla to date and will build on the progress made by previous models.

One of Tesla's new rivals in the electric vehicle market is Faraday Future, which takes its name from electromagnetism pioneer, Michael Faraday. Founded in 2014, this young company is in the early stages of production for its inaugural product, the all-electric, high-tech FFZero1 supercar. Presently, only prototype models exist but it has already impressed pundits with its futuristic appearance and top-of-the-range performance specs. The model has even caught the attention of the racing community, and Faraday Future has been signed up to race in Formula E for the 2016/17 season.

The company may not have any cars out on the track just yet, but it's promising an innovative design that will prove it's here to stay. Its unique Variable Platform Architecture (VPA) acts as the base platform of the FFZero1. The VPA is completely adaptable and batteries can be added or taken away to alter weight, power and range. To turn a vision into a practical result, virtual reality technology is used to see a car in its development stage, while the use of 3D printing enables ideas to go from idea to sketch to prototype as quickly as possible. These techniques will be used across the entire Faraday Future fleet, which will hit the road in 2018 by current estimations.

Tesla has its own supercharging stations that power up its vehicles in minutes rather than hours

Taking on Tesla

The automotive manufacturers who believe the future is electric

CHEVROLET BOLT

This affordable all-electric Chevy boasts a 320km range on one full charge of its nickel-rich lithium-ion battery pack.

VOLKSWAGEN E-GOLF

The Golf has two modes, Eco and Eco+, which help maintain a balance between top performance and fuel consumption.

HYUNDAI IONIQ ELECTRIC

As well as an electrified power train that can achieve speeds of 165km/h, the car has autonomous emergency braking.

MERCEDES-BENZ B250E

The advanced electric motor and high-capacity battery generate similar amounts of torque to the company's gasoline-powered saloons.

The FFZero1 concept is reported to produce a whopping 745 kilowatts of power

The FFZero 1's single seat interior is designed to create an engaging experience for the driver

FFZero1

Introducing Faraday Future's all-electric supercar concept

Aero tunnels

Two tunnels run through the vehicle, reducing drag and cooling the battery.

Connectivity

Smartphones can be connected directly to the car's steering wheel to enable real-time data interaction.

Intuitive information

The user interface displays important information clearly without distracting the driver.

High-tech seating

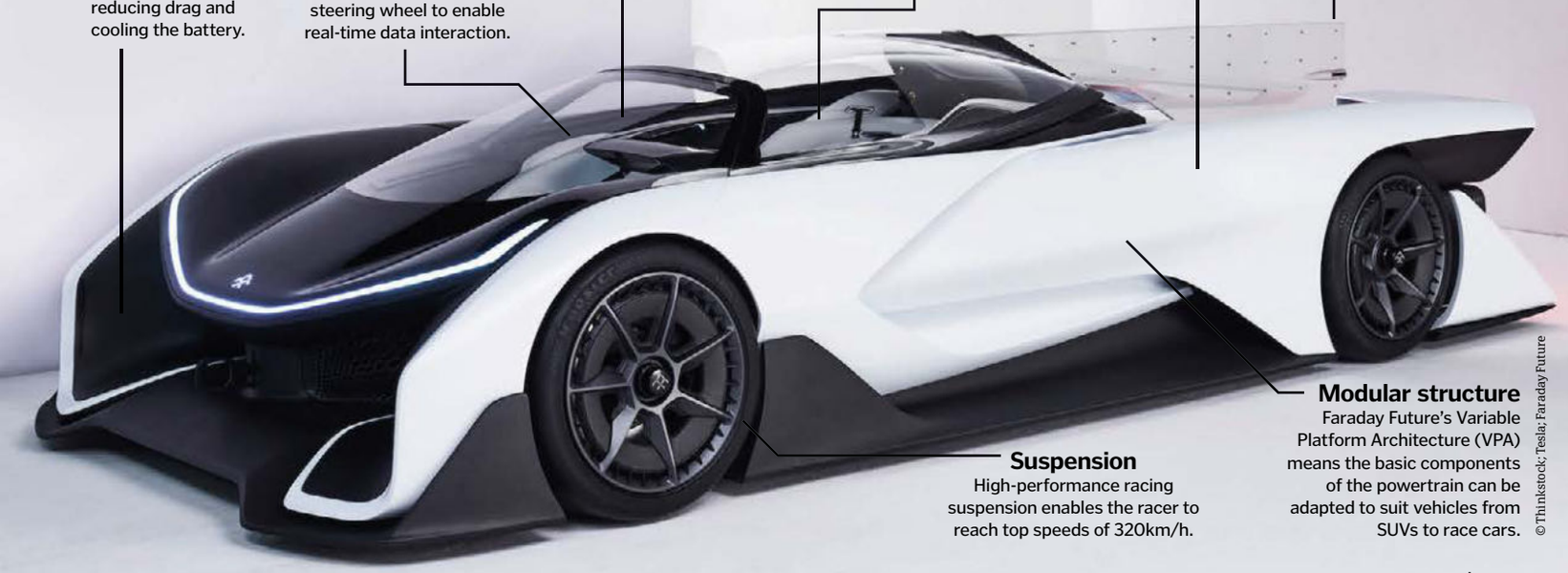
The seats are based on NASA's zero gravity design and will significantly reduce stress on the body at high speeds.

Supermaterial supercar

The body is constructed using carbon fibre, which is both lightweight and durable.

Tail fin

The angular structure of the FFZero1 improves aerodynamics while providing added stability.



Suspension

High-performance racing suspension enables the racer to reach top speeds of 320km/h.

Modular structure

Faraday Future's Variable Platform Architecture (VPA) means the basic components of the powertrain can be adapted to suit vehicles from SUVs to race cars.

The power system

How a motor converts electrical energy into acceleration inside a battery-powered vehicle

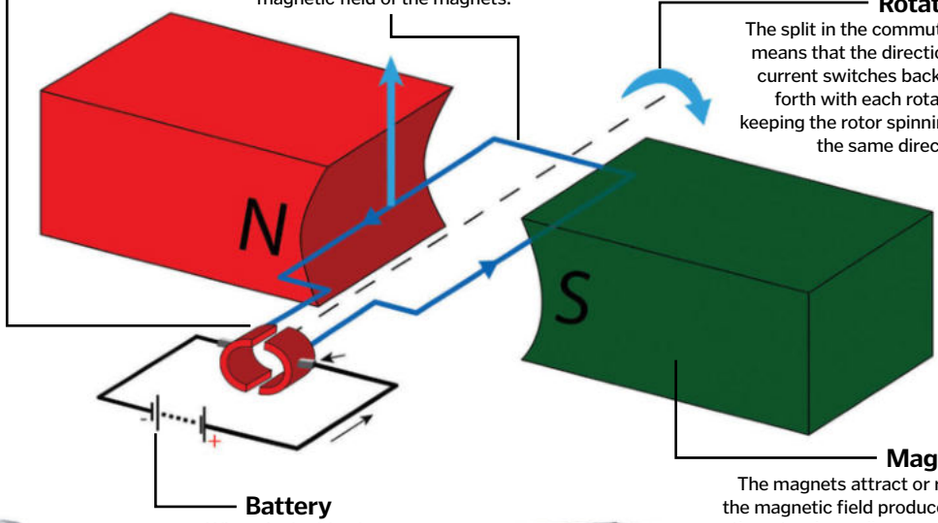
An electric car looks like a gasoline car from the outside. But take a look under the bonnet and you'll find a motor instead of an engine, and see that the power is supplied from a battery rather than a fuel tank. The motor converts electricity into mechanical energy, which is then used to turn the wheels. This process is regulated by the controller, which receives signals from the accelerator pedal and then delivers the corresponding amount of power to the motor.

Electric motors deliver high torque at low speeds and allow for rapid acceleration. The first generation of electric vehicles used a direct current (DC) system but more recent cars use alternating current (AC) instead. AC designs generally have a higher power-to-weight ratio, making them more efficient, and often require less maintenance.

"Electric motors deliver high torque at low speeds for rapid acceleration"

How a simple electric motor works

The principles behind the power system that gives electric vehicles a smooth ride



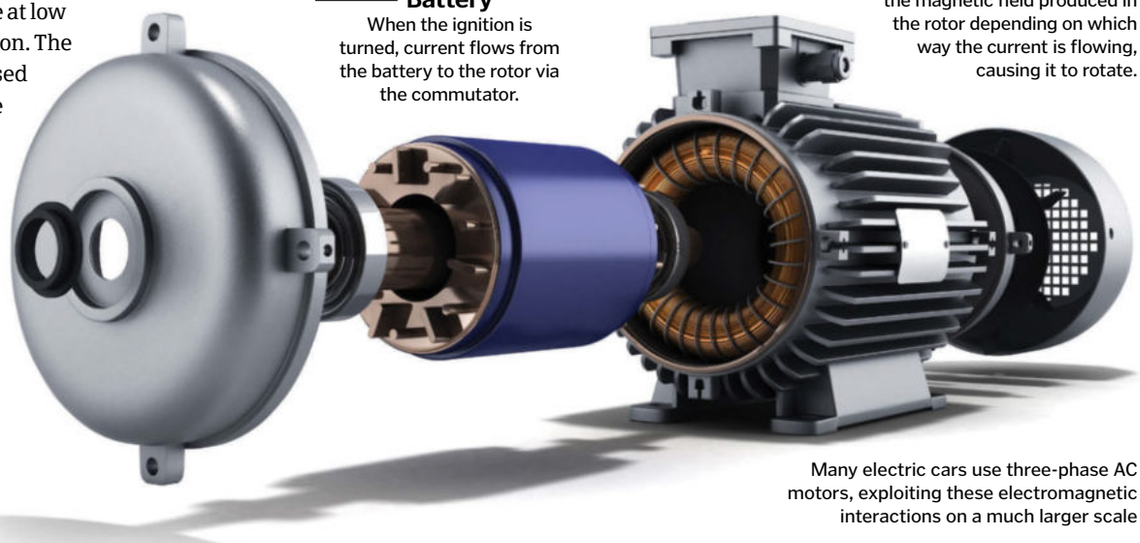
Commutator
This is essentially two halves of a metal ring. In DC circuits it reverses the current each time the rotor makes a half-turn.

Rotor
When current flows through the rotor coil, a magnetic field is created. This interacts with the magnetic field of the magnets.

Rotation
The split in the commutator means that the direction of current switches back and forth with each rotation, keeping the rotor spinning in the same direction.

Magnet
The magnets attract or repel the magnetic field produced in the rotor depending on which way the current is flowing, causing it to rotate.

Battery
When the ignition is turned, current flows from the battery to the rotor via the commutator.



Many electric cars use three-phase AC motors, exploiting these electromagnetic interactions on a much larger scale

Eco-friendly alternative fuels

Electric cars aren't the only vehicles taking on fossil fuels. There are several other energy sources that could help reduce our dependence on petrol and diesel...

HYBRIDS
These vehicles combine a conventional petrol or diesel engine with an electric motor, and so use less fuel than a standard car.

BIOGAS
Compressed methane gas can be used to power a conventional engine. This renewable fuel can be produced from human waste or manure.

ETHANOL
Bio-ethanol produced from corn or sugar cane could be used in fuel cell vehicles to produce electricity to power a motor.

HYDROGEN
The natural gas combines with oxygen to power a motor. Water and heat are the only by-products from this reaction.

Building better batteries

How will power unit production keep up with the growing demand for electric vehicles?

Over the past few decades, there has been a steady improvement in the efficiency and capacity of batteries. One problem that still remains is that, in order to provide the car with enough power, battery units are large and heavy. Lithium-ion batteries power most of today's electric cars, but new technologies could offer better alternatives. Lithium-air batteries are still in the research stage but they can store ten times more energy than lithium-ion cells of the same size, making them comparable to petrol or diesel in terms of energy density. Gold nanowire batteries are being developed to cope with regular recharging, and can last over 400 times longer than their lithium-ion counterparts.

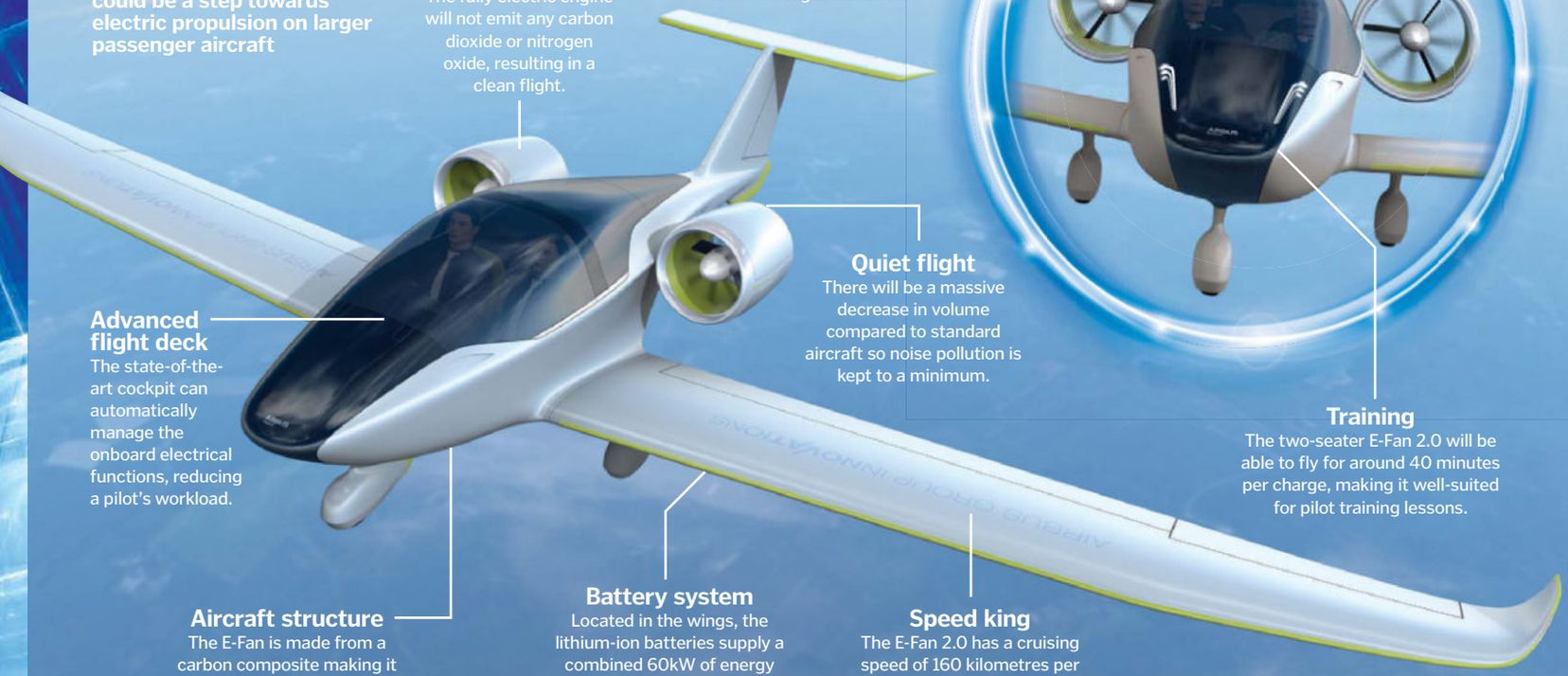
The company ahead of the curve is Tesla. In 2014 construction began on its Gigafactory, a new battery-producing complex in partnership with Panasonic. Located in the aptly named Electric Avenue, Sparks, Nevada, the factory will reach full capacity by 2020. By this stage, the aim is to produce more lithium-ion batteries at the Gigafactory than were produced worldwide in 2013. The $5-billion plant is currently just 14 per cent complete, but Tesla aims to have parts of the factory up and running in 2017 so that batteries can be used for the upcoming Model 3.

Tesla CEO Elon Musk has stated that the company's future hinges on the Gigafactory

Tesla rival Faraday Future is also constructing a Nevada base, with its $1-billion, 28-hectare factory

The E-Fan 2.0

Airbus' pioneering technology could be a step towards electric propulsion on larger passenger aircraft



Zero emissions
The fully electric engine will not emit any carbon dioxide or nitrogen oxide, resulting in a clean flight.

Simple controls
The cockpit is made to be as simple as possible and tablets can be connected to record flight statistics.

Quiet flight
There will be a massive decrease in volume compared to standard aircraft so noise pollution is kept to a minimum.

Advanced flight deck
The state-of-the-art cockpit can automatically manage the onboard electrical functions, reducing a pilot's workload.

Training
The two-seater E-Fan 2.0 will be able to fly for around 40 minutes per charge, making it well-suited for pilot training lessons.

Aircraft structure
The E-Fan is made from a carbon composite making it very light. It weighs just 500 kilograms when empty.

Battery system
Located in the wings, the lithium-ion batteries supply a combined 60kW of energy and there is a backup in case of an emergency landing.

Speed king
The E-Fan 2.0 has a cruising speed of 160 kilometres per hour and a maximum speed of over 200 kilometres per hour.

Electric jets take to the skies

The exciting concepts that could make commercial electric flight a real possibility

Every day, 8 million people take to the skies in passenger aircraft. The aviation industry is still growing and anyone who strikes gold with a sustainable electric power system could prompt a new age of aviation. The history of electric aircraft goes back to 1973 when a modified Brditschka HB-3 motor glider took flight, but there hasn't been very much progress since. While we can't yet produce batteries that can match the power produced by commercial aircraft engines, the advent of electric air travel might not be as far off as it seems.

NASA is using an experimental electric aircraft nicknamed Maxwell to demonstrate how battery-powered planes would be quieter and more efficient, with the environmental benefit of no carbon emissions. Leading aircraft manufacturer Airbus is also investigating the future of eco-friendly flight with their plug-in plane, the E-Fan. In 2015, this small plane made history as the first all-electric, twin engine aircraft to cross the Channel. Following this success, Airbus is now working on the E-Fan 2.0, a production model based on the original, as well as a hybrid version named the E-Fan Plus.

Not content with revolutionising road travel, Tesla CEO Elon Musk has also been considering electric aviation. When asked about what his next great idea would be, he replied "I have been thinking about the vertical takeoff and landing electric jet a bit more [...] I'm quite tempted to do something about it."

The world's first electric vertical take-off aircraft, the Lilium, will eliminate the need for runways

e-Genius

In July 2015, a small two-seater plane called the e-Genius became the first electric aircraft to cross the Alps. Not content with performing a world-first flight just the once, the pilots recharged and made the return flight on the same day.

Built by the Institute of Aircraft Design at the University of Stuttgart, the e-Genius was developed to participate in NASA's Green Flight Challenge in 2011. The competition encourages teams to design planes that maximise fuel efficiency, reduce noise and improve safety. The aim is that the innovations competitors come up with in this contest can some day be applied to commercial, private and military planes in the future.

The e-Genius is powered by high-energy density lithium-ion battery packs, which run a 60-kilowatt motor. This provides a maximum range of over 400 kilometres on a single charge.

The battery-powered e-Genius has a top speed of 160 kilometres per hour

NASA's electric dreams

Discover more about Maxwell and the future of electric air travel

Matt Redifer
X-57 Chief Engineer

Why has NASA branched out to electric planes?
For a very long time the idea of an electric plane has been hampered by the weight and energy density of batteries, or the additional weight of other electric systems such as turbo generators. Now that the weight of batteries has decreased considerably along with corresponding increases in energy density, a battery-powered electric plane is more practical. One obvious advantage of an electric aircraft is zero emissions, depending on the grid used to charge the batteries. However, NASA is not just interested in electrifying a conventionally powered aircraft. The idea of integrating the electric propulsion system with the airframe aerodynamics provides another tool in the designer's toolbox to improve overall efficiency of the aircraft. Electric motors are about three-times more efficient than conventional engines, considerably lighter, and, since they are not air-breathing, their performance does not decrease with altitude.

What electrical system do you use?
X-57 is an all-electric battery-powered aircraft. The battery is 47 kilowatt-hours, operates at 460 volts, and weighs 358 kilograms.

How does it work and why the unusual design of 14 motors and propellers?
The two motors on each wing tip are referred to as the cruise motors. Placing the motors on the wing tips takes advantage of an opportunity to recover energy from the vortices created at the wing-tips. The other 12 motors are referred to as the high-lift motors, six on each side of the wing. The motors are distributed along the leading edge of the wing in a configuration known as DEP, or Distributed Electric Propulsion. The high-lift motors are only operated during take-off and landing conditions. They blow air over the wing, providing additional lift for these flight conditions. This allows the wing to be designed with a shape that is optimal for the cruise condition, as opposed to a conventional wing that must be larger to generate the lift needed at take-off and landing. The propellers on the high-lift motors fold back against the high-lift nacelles during cruise to prevent more drag. This implementation of Propulsion Airframe Integration (PAI) when combined with electric motor efficiency is expected to deliver a five-times improvement in efficiency over the conventionally powered aircraft.

NASA's X-57 'Maxwell' has 14 electric motors built into its wings

"The advent of electric air travel might not be as far off as it seems"

Do you have plans for any other electric aircraft?
Yes, there are several conceptual vehicles being considered for the next generation of electric aircraft. A direct follow-on to X-57 would be an all-electric short haul commuter aircraft capable of caring eight to nine passengers a distance of 370 kilometres or less. Other electric aircraft concepts exist for larger scale aircraft that take advantage of hybrid configurations that allow for smaller conventional engines, with electric motors augmenting over-all system performance by taking advantage of another PAI technique known as Boundary Layer Ingestion (BLI).

What is your goal with electric air travel?
NASA's overall goal is to develop electric aircraft technology, validate models that predict substantial improvements in efficiency by performing both ground and flight testing, and transfer the technology to industry for adaptation into commercial aviation. X-57 will demonstrate through flight test the increased aerodynamic and propulsive efficiency obtained through PAI and DEP. Additional potential benefits of electric propulsion include reduced or eliminated emissions, lower community noise, and lower operating costs.

What is the future of electric aircraft?
The future for electric aviation could be very bright if the anticipated increases in efficiency are proven in flight test, and batteries and other electric power systems continue to become more energy dense and safer. System concepts such as DEP and BLI give designers innovative methods to explore unique designs that are not possible without electric systems.

Battery-powered boats

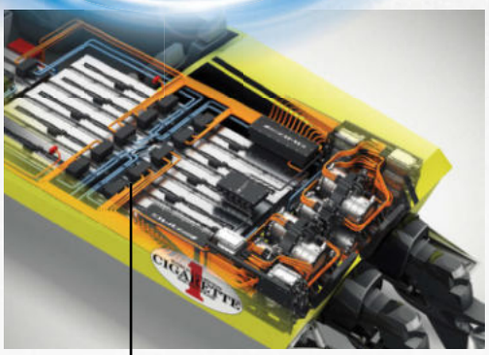
Could this be the very best in seafaring transport?

With a 75km/h top speed, the Edorado 7S is another high-performance electric power boat

Electric vehicles on the water aren't a new phenomenon. Unlike cars and aircraft where petrol and diesel quickly became the fuels of choice, boats and ships had a slightly different evolution. Steam, naphtha and electric power were all originally used to supplant the age of sail, but petrol power soon proved superior for seafaring missions in the two world wars.

Electric power for boats can be much easier to implement than on land or in the air, as it just requires a battery to run the outboard motor. Power issues and range anxiety have meant that until recently, electric engines were mainly used in hybrid powerboats with the electricity handling slow cruises and an internal combustion engine kicking in when full throttle was required. In the near future, high-powered batteries like lithium-sulphur and lithium-air will enter production, providing more efficient electric travel.

Presently, sleek speedboats and cost-effective ferries are using full electric power to transport people across the waves both quickly and practically. Cheaper, quieter and potentially more powerful, fleets of electric boats may soon be docking in harbours all over the world.

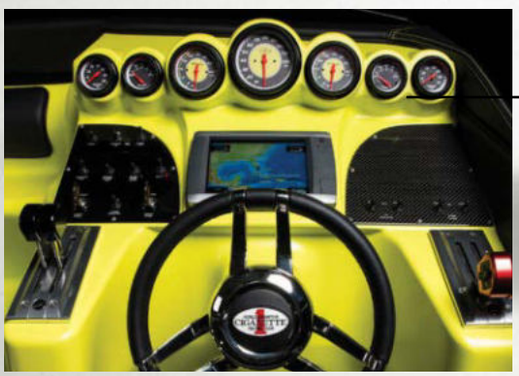


Top speed
The Electric Drive can reach top speeds of over 160 kilometres per hour.

Charging
The batteries can be fully charged in seven hours, but the Electric Drive can also be fitted with onboard charges to reduce this to three hours.

Plug-in powerboat

Meet the world's most powerful electric performance boat – the Cigarette AMG Electric Drive



Behind the wheel
The instruments and dials on the Electric Drive include information on the current speed, battery status and motor output.

Handling
The boat's electric motors and battery are positioned low down and close to the back of the boat to provide a low centre of gravity and improve stability.

Inspired by motorsport
The manufacturers used advancements from the world of Formula 1 when developing their battery system.

Power source
There are four high-voltage lithium-ion batteries in total, generating a total electrical output of 2,400 kilowatts.

Eco-friendly ferries

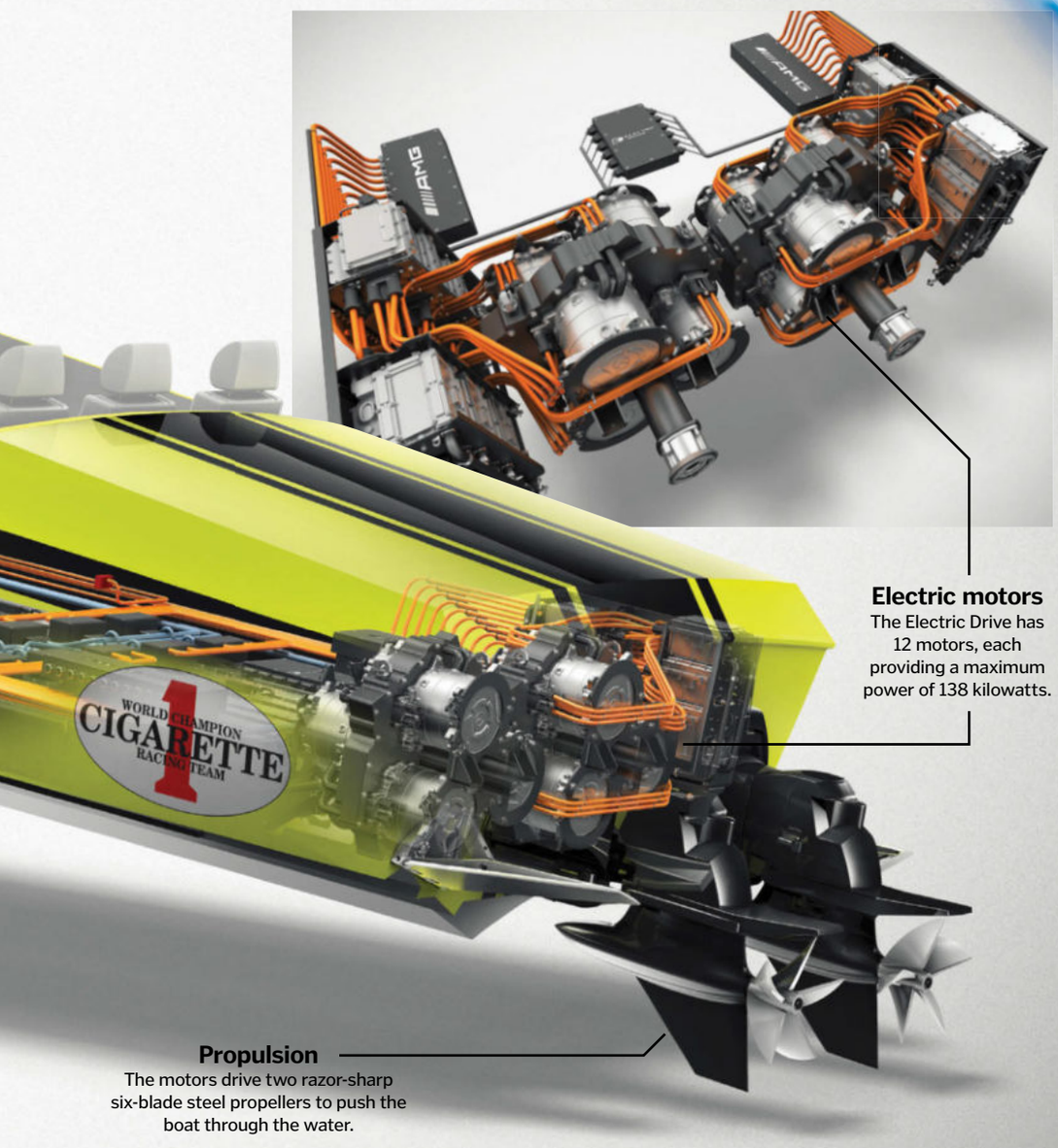
German engineering giant Siemens currently has a fully electrical-powered ferry in operation in Norway. The economical ferry reduces the cost of fuel by 60 per cent as it takes passengers across the Sognefjord, the largest fjord in the country. The BlueDrive PlusC system works using one lithium-ion battery on board, with two more at either shoreline. The batteries are boosted up at these charging stations, which themselves are powered by hydro-electricity. As well as the batteries, the thrust control and energy management systems are electric and its aluminium hull means it's half as heavy as standard ferries.

Electric watercraft

The first all-electric hydrofoil to zoom across the water on purely electric power is almost here. Constructed by high-tech development company Quadrofoil, the Q2S's battery management system means it can travel up to 100 kilometres on a single charge at speeds of up to 40 kilometres per hour. The tech is sophisticated and includes a touchscreen steering wheel that also acts as a detachable key. The craft travels with minimum water resistance and a light hull makes handling simple.

The Q2S has a built-in anti-collision system that absorbs shocks from the water impact

It won't be long before the first all-electric hydrofoil is in action



Electric motors
The Electric Drive has 12 motors, each providing a maximum power of 138 kilowatts.

Propulsion
The motors drive two razor-sharp six-blade steel propellers to push the boat through the water.

"The economical ferry reduces the cost of fuel by 60 per cent"

Electric vehicles by numbers

500,000
The number of cars Tesla aim to produce each year by 2020

30%
The amount by which the Gigafactory will help drive down battery costs

400km/h
Top speed of the Lilium electric VTOL jet concept

$1bn
The estimated cost of Faraday Future's Nevada factory

230mn
The approximate number of e-bikes in China in 2015

0-100 km/h in 2.5s
The new Tesla Model S P100D is the quickest production car in the world

Day in the life of a Crossrail engineer

How do you build a railway underneath one of the world's busiest cities?

In 2018, a new purple line will appear on London's tube maps, marking out the central section of the city's newest transport route – Crossrail. As Europe's biggest engineering project, it has brought together thousands of construction workers, designers, scientists, architects and engineers to construct an East-West highway of remarkable rail tunnels – 42 kilometres of which run under London itself. Weaving tunnels through an already-packed subterranean network is a huge job that comes with lots of challenges. So, to learn more about how it's done, we spent the day with Juliet Murray, a track field engineer in Crossrail's Railway Systems team.

Engineer Juliet is originally from Australia. Before joining Crossrail, she worked for London Underground

PREPARATION IS KEY
7am

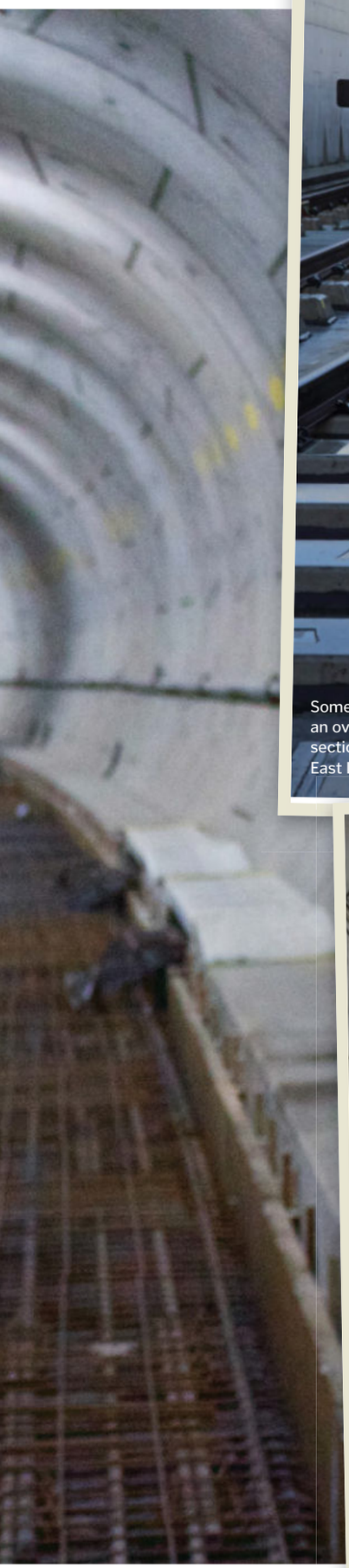
I leave the house by 7am, making sure that all of my Personal Protective Equipment (PPE) is packed and ready to go. On-site, I need to wear bright orange trousers and jacket, along with steel-toe-capped boots, a hard hat, gloves and safety glasses. But my work day always starts at my desk.

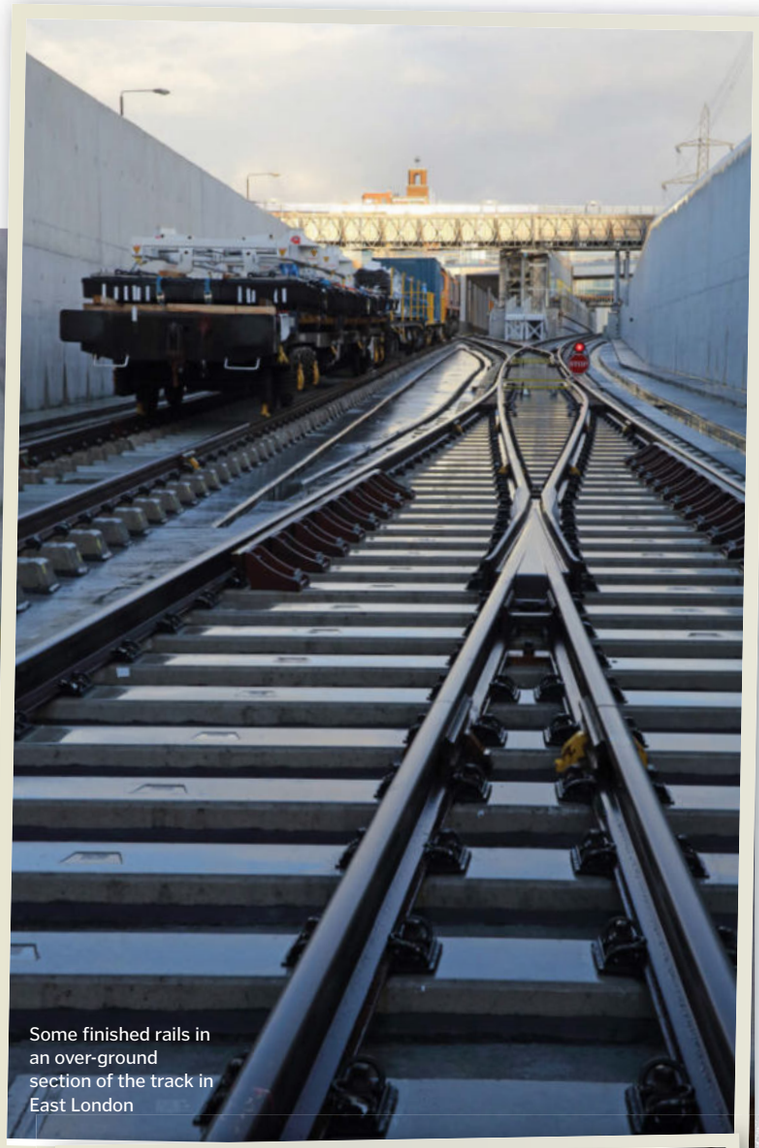
REVIEW PROGRESS
8am

Crossrail's work never stops, with construction going on 24 hours a day on some sites. So, the first thing I need to do is review progress reports and drawings, and check for any issues. On a project of this scale, we make detailed plans for every activity, so my next task is to look at what's planned for my site in the day ahead.

GO DOWN TO SITE
10am

This is my favourite part of the day. I put on my PPE, and go down a long staircase to the tunnels. As the engineer on site, I have a lot of different roles – my main one is to make sure that the work we do is the best possible quality. That means





Some finished rails in an over-ground section of the track in East London

Multipurpose gantries are used to lift railway sleepers into place

checking everything from the concrete to overseeing track alignment.

INSPECTING NEW TRACKS
10.30am

Train tracks are made from lots of pieces, so we use equipment like multipurpose gantries to transport and accurately position many concrete sleepers (70,000 in all) and 108 metre-long sections of rail into the tunnels under central London. I oversee all of this activity, and work with the contractor to ensure that we stay on plan, and produce the best tracks possible.

ENSURING EVERYONE'S SAFETY
11am

As well as overseeing the construction of the tracks, I also need to make sure it's the safest site possible. The railway systems team is spread across the entire route, but there will be around 100 workers on each site every day. I want them to feel safe and supported as they work, and ensure that any concerns they have are acted on.

TRAIN SOUND-PROOFING
12pm

In certain sections of Crossrail's route, we use a special type of rail that floats on a combination of heavy-duty springs and squishy elastomer bearings. This 'floating track slab' greatly reduces the amount of noise the trains produce as they run along the track. Installing it is very challenging though, as every component has a role to play.

TEAMWORK
2pm

Planning is only one part of a construction project – unforeseen challenges can also arise, and with tight deadlines, they need to be solved there and then. I love working with the construction teams and designers in this way – engineering is a dynamic job, and you need to be good at thinking on your feet.

REPORTING
3.30pm

I spend my afternoons back at my desk, reporting on the progress made on site that day. Thousands of people are involved in the project, so everything must be documented. This involves updating the technical reports that will be checked by the chief engineer's group, and recording data in several databases, so that we're ready to start again tomorrow!

All about SNAKES

Slither this way to learn everything you need to know about these stealthy serpents

In general, snakes get a bad rep. They are animals that are traditionally treated with suspicion, as sly and cunning creatures. The truth is, they are both those things. But they're also remarkable animals with amazing defences and incredible adaptations. Their ability to be some of the scariest animals on our planet without even having legs is no mean feat!

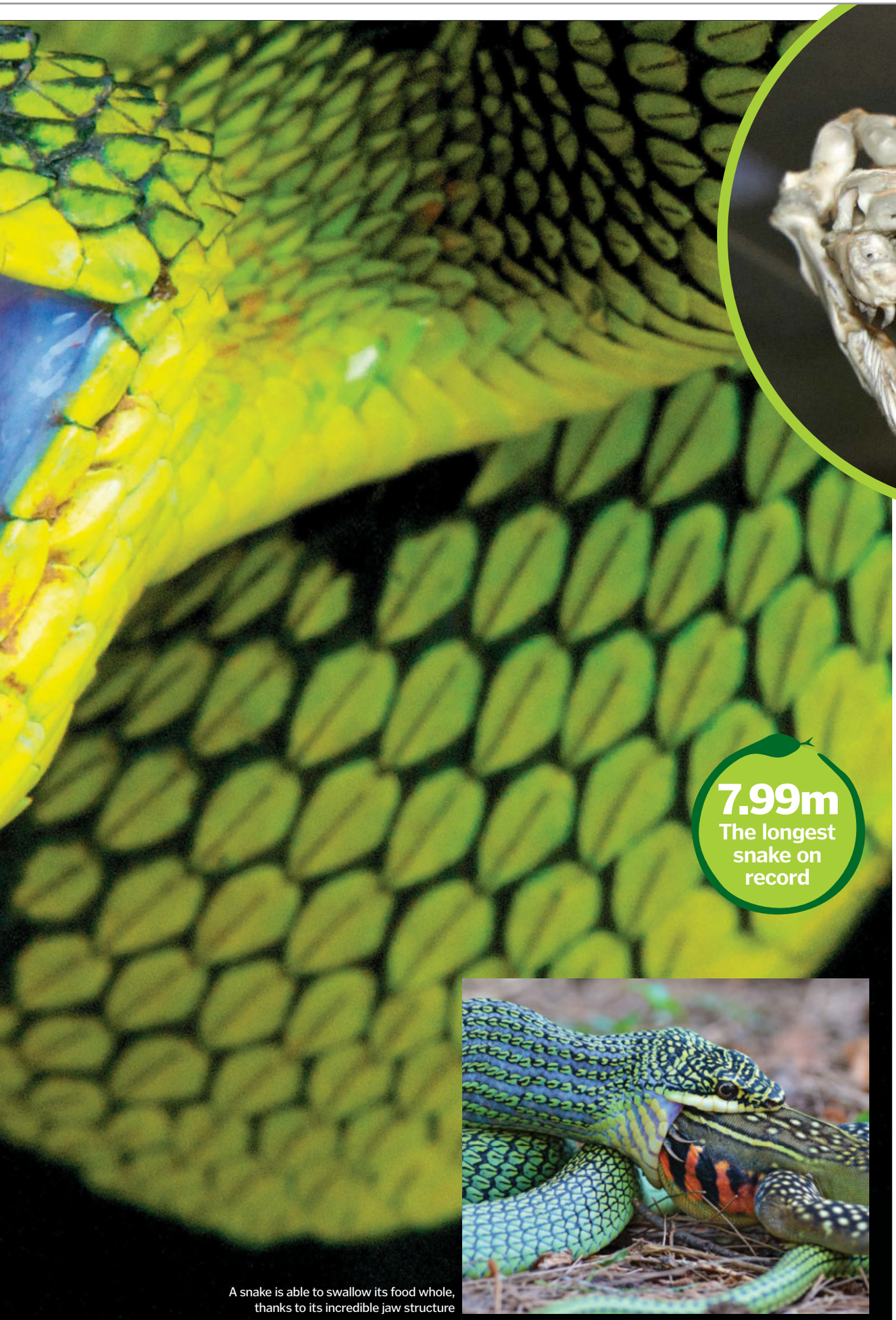
It's not clear exactly when snakes evolved in their current form, but scientists do believe that their ancestors were four-legged, lizard-like creatures. A fossil dating back 113 million years is thought to be the most primitive ancestor of the modern-day snake, and has a serpentine body but with the addition of four tiny legs. From these humble beginnings, snakes have conquered most environments on Earth, and range from the colossal, water-dwelling, constricting leviathans – such as the Amazonian anacondas – to the tiny, noodle-like threadsnakes. The UK has only three native snake species, and the adder is the only venomous variety. This snake lives in rough, open countryside, but there's no need to worry – it's pretty shy, and no one has died from an adder bite in more than 40 years.

Nearly 3,000 species on Earth

Snakes have an affinity for water, and all snakes can swim. Some species are better at underwater life than others, such as sea snakes that can stay submerged for an hour or more. Despite their aquatic surroundings, these snakes can't drink seawater, and can go for months without drinking fresh water. It's proposed that they rehydrate with fresh water when heavy rains fall over the ocean.

The majority of snake species aren't venomous, but for those that are, this is as much of a defence mechanism as it is a hunting tool. Each venomous snake species has its own special toxic cocktail of venom, containing a mix of proteins and enzymes designed to immobilise both predators and prey. Some venom works by attacking the nervous system; others by causing viscious damage to blood and tissue.

Some species (including vipers, pythons and boas) even have a superpower. They possess a sixth sense: the ability to detect heat signatures and see in infrared. This, coupled with their supreme strength, agility, venom and lightning-fast reflexes, means that a snake's prey doesn't really stand a chance.



How do snakes swallow supersized meals?

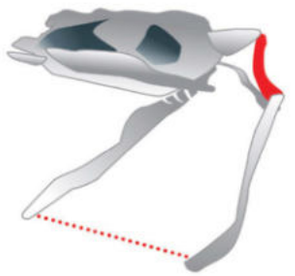
Uncover the mouth mechanics of snakes

7.99m
The longest snake on record

A snake is able to swallow its food whole, thanks to its incredible jaw structure

Neutral jaw

While the snake isn't eating, its jaw is relaxed. The lower jaw isn't fused, and is joined with muscles that allow the two parts to move independently.



Open wide

The quadrate bone (shown in red here) acts as a joint to allow vertical and horizontal movement, and opens up to an angle of 150 degrees. Ligaments at the base of the jaw enable the bones to spread apart.

Inside a serpent

No legs? No problem! Check out the science beneath the snakeskin

A snake is essentially a long bag of stomach and muscle, and much of a snake's internal features are focused on its ability to eat really large items. The ribs are flexible to allow for expansion, and the heart is free to move (as there is no diaphragm) so that it doesn't get damaged when the snake forces a large meal down the oesophagus.

A snake has small scales on its back and sides, and wider ventral scales (on the underside) that perform like treads on a tyre. The large plates enable the snake to grip the ground while its powerful muscles propel it forward.

227kg
Average weight of adult female anaconda

Heart
A snake's heart has just three chambers, yet it still functions like a four-chambered heart.

Thyroid gland
This gland secretes essential hormones. It's thought that it has a role in shedding and growth.

Vertebrae
Dependent on species, snakes have 200-400 vertebrae along the length of their bodies, with a pair of ribs attached to each one.

Liver
This is the snake's largest organ. Among other functions, it processes waste, and excretes bile and digestive enzymes.

70%
of snake species lay eggs

Lungs
Most snakes don't have a functional left lung, and their right lung is much larger in order to compensate for this.

Skin
Scales of snakeskin are dry, despite looking slimy. They are made of keratin, the same substance as in human fingernails.

Kidneys
Like mammalian organs, a snake's kidneys filter the blood and remove waste products.

How snakes move

Concertina
The snake pulls its body into alternating bends to grip on, and then moves forward at it stretches out – a method often used for climbing trees.

Serpentine
The fastest and most common method that looks like 'slithering', the head moves side to side, and the body follows, pushing off the ground as it bends.

Sidewinding
Used where there is nothing to grip on to, such as sand, this method involves the snake making an S-shape and throwing its body sideways across the ground.

Caterpillar
Also called 'rectilinear' motion, this is where the snake moves just like a caterpillar, creating waves with its body up and down instead of side-to-side.

Eyes
Snakes have no eyelids. Instead, each eye is protected by a transparent scale, known as a spectacle.

Gall bladder
Bile from the liver is stored here and released into the small intestine when it is needed to break down food.

Intestines
These long, narrow and coiled tubes are where nutrients from snakes' meals are absorbed.

The sidewinder adder has eyes on top of its head, enabling it to be totally buried and still watch for prey

In the serpent world, a triangular jaw can often mean "I'm venomous!"

Teeth & venom

A fearsome part of every snake is its teeth. Here's the lowdown on those serpentine pearly whites...

Snakes swallow their food whole, so their teeth aren't used for chewing, but the dentition that a snake sports is often determined by the way it hunts. Regardless of type, snake teeth are all backward-curved, which is a handy adaptation to help the snake secure its quarry.

There are three types of snake teeth: first up are the sharp yet even teeth that don't deliver any kind of venom. These belong to non-venomous snakes, such as boas and pythons.

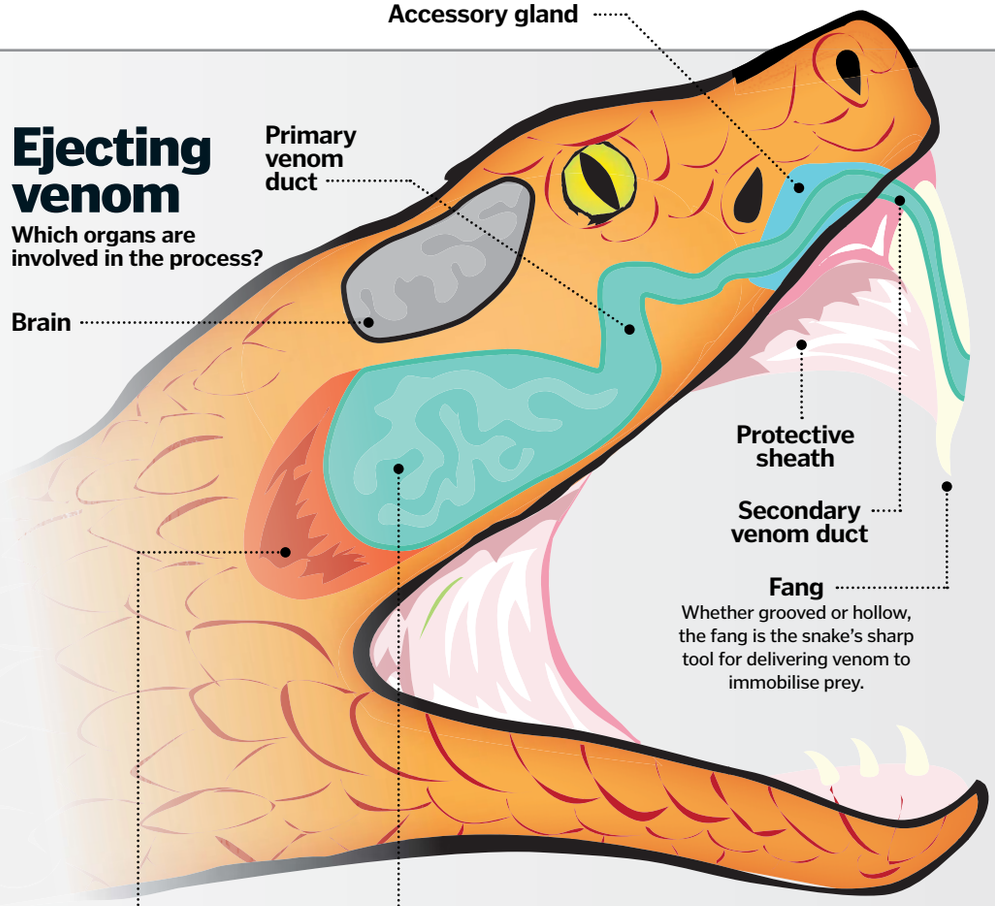
Snakes with prominent fangs come in two types: grooved and hollow. The former is more common and, as the name suggests, they have a channel down which venom is delivered. These can be found at the front of a snake's mouth – think of the terrifying 'smile' of the king cobra, complete with incredibly sharp weapons ready to strike. But they can also be found at the back of the mouth, like in the hognose snake. Rear-grooved teeth mean that the snake has to force prey to the back of its mouth to dispense venom.

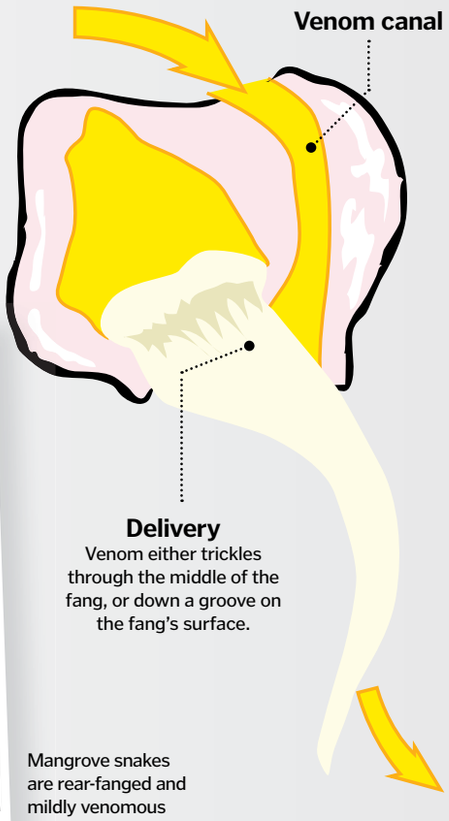
The hollow-fanged snakes include vipers and cobras, some of the most deadly serpents. Their prominent fangs have tubes through which venom flows, directly entering prey from syringe-like teeth to do their deadly work. These fangs often fold in against the roof of the snake's mouth until the opportune moment to strike.

Fangs are attached to venom sacks behind the snake's eyes. The venom is delivered as muscles in the snake's head compress the sacs to administer a noxious dose.

Ejecting venom

Which organs are involved in the process?





"Snakes swallow their food whole, so teeth aren't for chewing"

Mangrove snakes are rear-fanged and mildly venomous

600 species of venomous snake

Preparing to extract snake venom

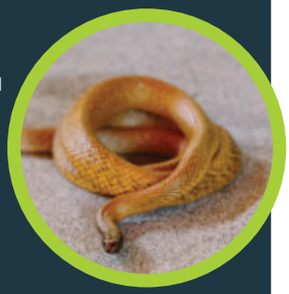
How to milk a snake

Extracting venom is vital for making life-saving antidotes

1 Prepare apparatus
Snake milkers will prepare their apparatus before beginning. They use a jar to collect the venom, and either a glass funnel or a stretched piece of latex to hold the fangs.

2 Prepare the snake
The pros are used to handling snakes, so the snakes are relaxed and kept happy and healthy. The snake is removed from its tank and brought to the collection point.

5 of the most dangerous snakes

Inland taipan

Found in the semi-arid bush of eastern central Australia, the venom of the inland taipan is by far the most toxic of any in the world. However, unlike its aggressive cousin, the coastal taipan, this snake actually shies away from humans.

King cobra

This is the longest venomous species, and to add extra menace to its crippling venom and huge fangs, it can raise a third of its body into the air and flare its hood. A single bite can kill an elephant.

Saw-scaled viper

One of Asia's most dangerous snakes, its venom isn't as toxic as other species', but this snake lives in populated areas and is quick to bite if it's feeling threatened.

Boomslang

Once thought to be harmless, this rear-fanged snake actually has potent venom, although it is generally a placid snake. It is a tree dweller and lives in sub-Saharan Africa.

Black mamba

This snake is brown in colour, and gets its name from the colour of the inside of its mouth, which it displays when threatened. It is Africa's longest and one of the world's fastest snakes.

Anti-snake defences

The ingenious ways animals avoid the jaws of death

Meerkat mobs
Meerkats show strength in numbers as they mob a puff adder. Mobbing involves surrounding the snake with tails up, to make them look like one larger animal.

50 years
The lifespan of some species in captivity

Venom immunity
Snakes form a large proportion of a honey badger's diet. They defend against the poison on a molecular level; the receptors in muscle cells block the venom's neurotoxin.

Quick movements
When living near snakes, squirrels have adapted escape techniques. Fluffing up their tails makes them appear larger, and lightning-quick reflexes help to avoid strikes.

3 Position the head
The snake's head is held in the milker's hand, with the thumb and index finger placed at the back of the head, behind the angle of the jaw where the venom glands are.

4 Expose the fangs
The snake's fangs are exposed, and then the snake either bites down on the latex cover, piercing it with its teeth, or a glass funnel is held at the back of the fangs.

5 Massage venom glands
Gently squeezing above the venom glands helps to expel venom, which comes out through the fangs and is collected in the jar. Only a few micrograms can be milked at a time.

6 Make the antivenom
A tiny amount of venom is injected into another animal, which produces antibodies in response. These are collected from a blood sample and used to make an antivenom.

Earth's atmosphere

The clouds are just 0.1 per cent of the way up into the sky. Here's what lies above…

99 per cent of Earth's atmosphere is within an altitude of 20km

Air pressure decreases exponentially the higher you go. But the temperature doesn't follow this smooth pattern; it falls and then rises in alternating bands.

The ground heats the lowest layer of the atmosphere, called the troposphere, so this layer gets colder the higher up you go. As the air gets colder, the water vapour precipitates and falls as rain or snow, and by the time you reach the top of the troposphere at around eight to 12 kilometres up, the air is almost completely dry. This is the start of the stratosphere, where the temperature starts rising again as a result of a large number of ozone molecules absorbing ultraviolet radiation from the Sun.

Once the ozone thins out, you reach the mesosphere and the temperature falls again, down to as low as -90 degrees Celsius. All the shooting stars you see are actually meteorites burning up as they enter the mesosphere.

Even at altitudes normally considered to be outer space, there is no hard edge to the atmosphere. The air just gets thinner and thinner. The International Space Station (ISS) actually flies through the layer above the mesosphere, which is known as the thermosphere. Even though individual gas molecules are so far apart that they can fly for a kilometre without hitting one another, there is still enough atmospheric drag to cause the ISS to lose about two kilometres of altitude per month. The final, outermost layer is the exosphere, where the atmosphere thins so much that it eventually just blends into space.

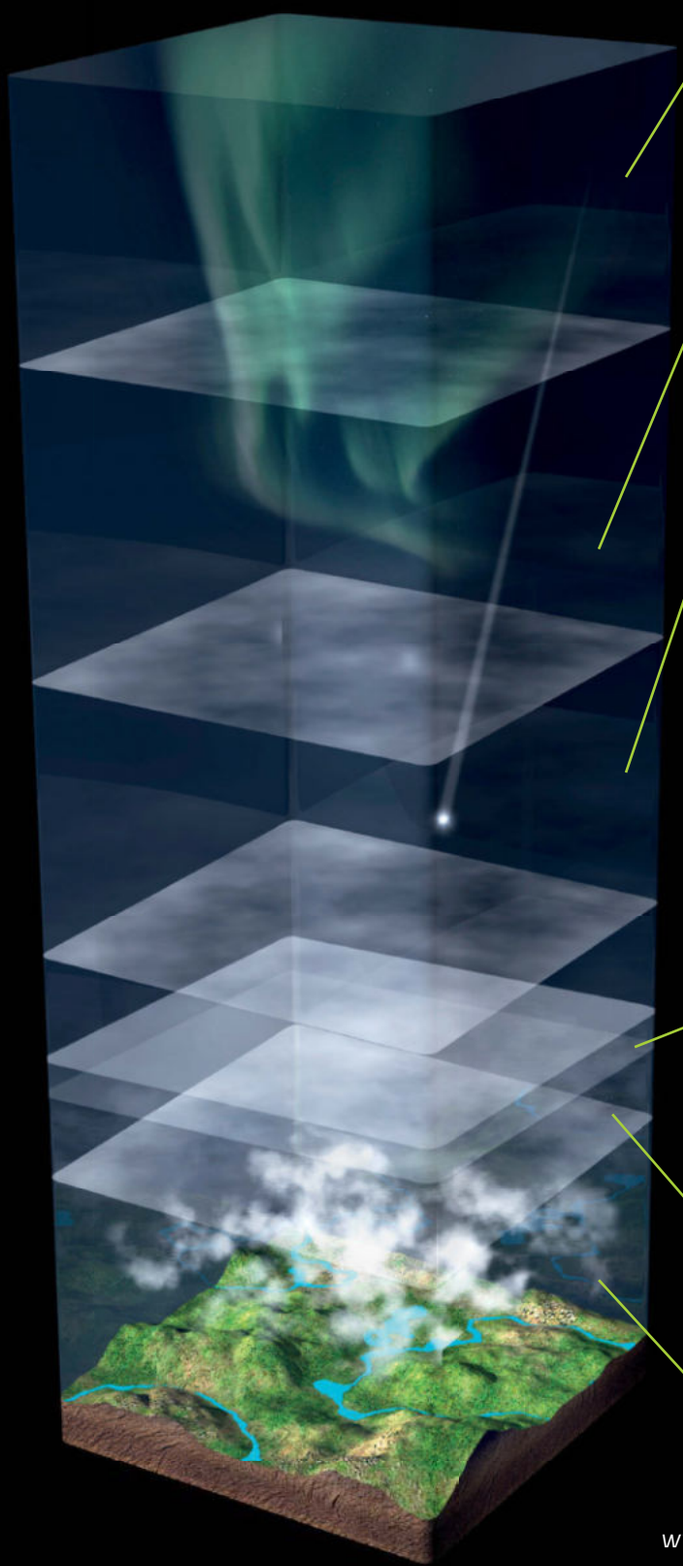
Space Shuttle Endeavour against the mesosphere (blue), stratosphere (white) and troposphere (orange)

Where does space start?

The atmosphere tapers off gradually, so there is no obvious point where Earth ends and outer space begins. However, we have come to a consensus based on science. The higher a plane flies, the less lift it gets from the thinner air, and the faster it must travel to stay aloft. In the 1950s, physicist Theodore von Kármán calculated that above 100 kilometres, a plane would have to travel so fast that it would be in orbit. This altitude is now known as the Kármán line, and is the internationally accepted boundary of space.

Atmospheric layers

Each region of the atmosphere behaves quite differently from the ones above and below it



Exosphere
600 to 10,000km

Most satellites orbit here. Individual air molecules are separated by hundreds of kilometres of vacuum.

Thermosphere
85 to 600km

The temperature in this layer can reach 1,500 degrees Celsius but the air is so thin that it barely carries any heat energy at all.

Mesosphere
50 to 85km

Temperatures towards the top of this layer can fall to -90 degrees Celsius.

Ionosphere
48 to 965km

This overlaps the mesosphere, thermosphere and exosphere. It is where ultraviolet radiation ionises air molecules, creating a layer that reflects radio waves to Earth.

Ozone layer
15 to 35km

The ozone molecules absorb between 97 and 99 per cent of the ultraviolet light reaching Earth from the Sun.

Stratosphere
12 to 50km

Jet planes can reach this high. Air pressure drops to one thousandth of that at sea level.

Troposphere
0 to 12km

This is the densest layer of our atmosphere and is where all our weather occurs.

Bring the first tank to life with TANK100

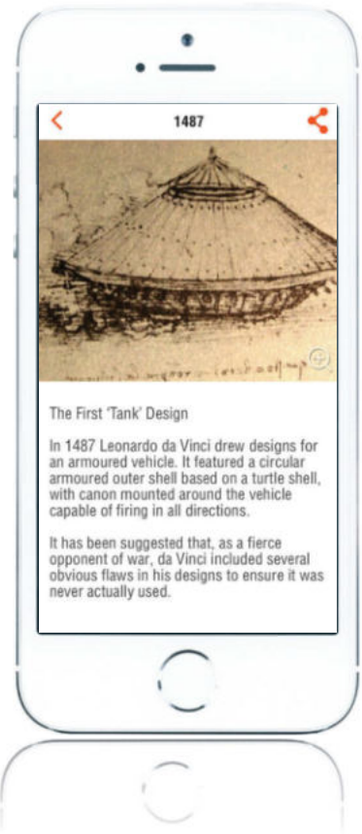
Wargaming launches a free AR/VR app to commemorate a century since the tank first entered battle in World War I

Wargaming, the creator of the massively multiplayer online game *World of Tanks*, has released a new augmented and virtual reality app to honour the first use of Britain's World War I secret weapon, the Mark I tank, which roared onto the battlefield on 15 September 1916, in the third month of the bloody Battle of the Somme.

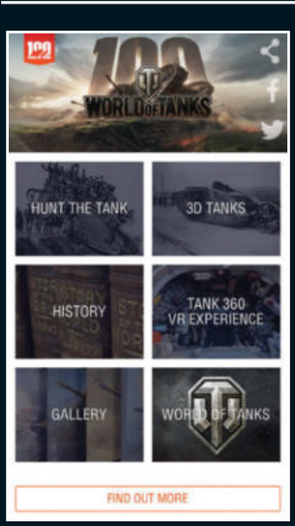
Available for free on iOS and Android devices, *Tank 100* lets the user discover life-size AR Mark I tanks in towns and cities across the UK, view stunning 360-degree VR films of tanks in action, and uncover the fascinating history of armoured warfare and mechanical innovation in partnership with The Tank Museum, Bovington.

Tank 100 won't end with the Somme centenary; further updates promise to expand the range of tanks, mark future anniversaries, and even allow the user to take control of the tank themselves.

What are you waiting for? Use the QR code to download *Tank 100* from the App Store.



Tank 100 features



Tanks Now
Use augmented reality (AR) to place a 3D tank on screen. Resize and orientate it to create your own real-world Mark I cameo that you can save and share.

Tank Hunter
Discover 3D tanks dotted around the UK's towns and cities. Use AR to view the tank full size and unlock additional video content, such as a 360-degree interior view that can be paired with Google Cardboard for a fully immersive experience.

AR Tank Trigger
An image or QR code can be used to trigger a 3D tank on any given surface.

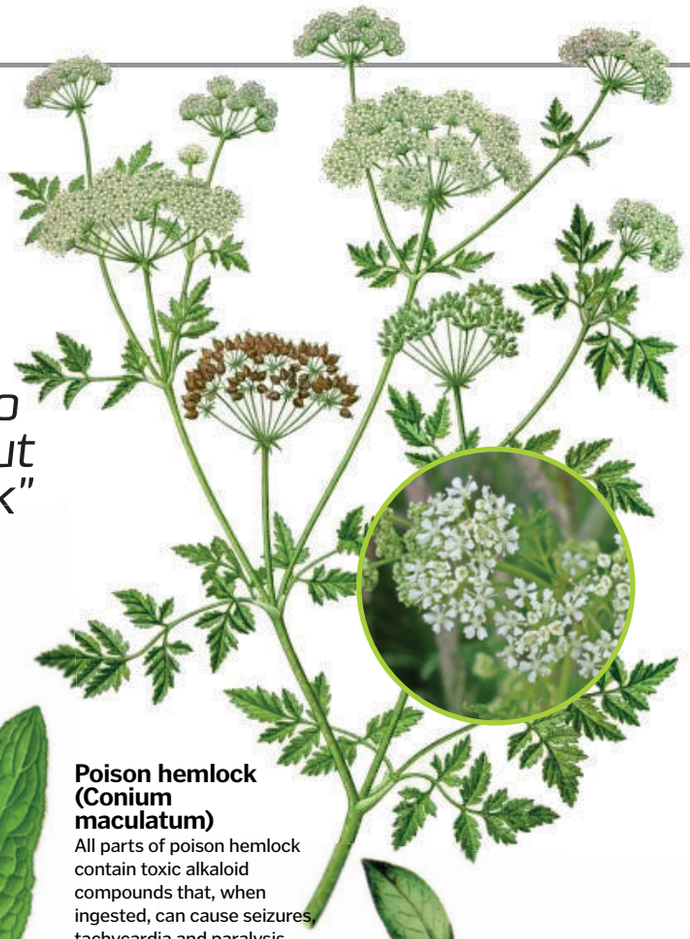
Poisonous plants

"It takes four castor seeds to kill a human, but 80 to kill a duck"

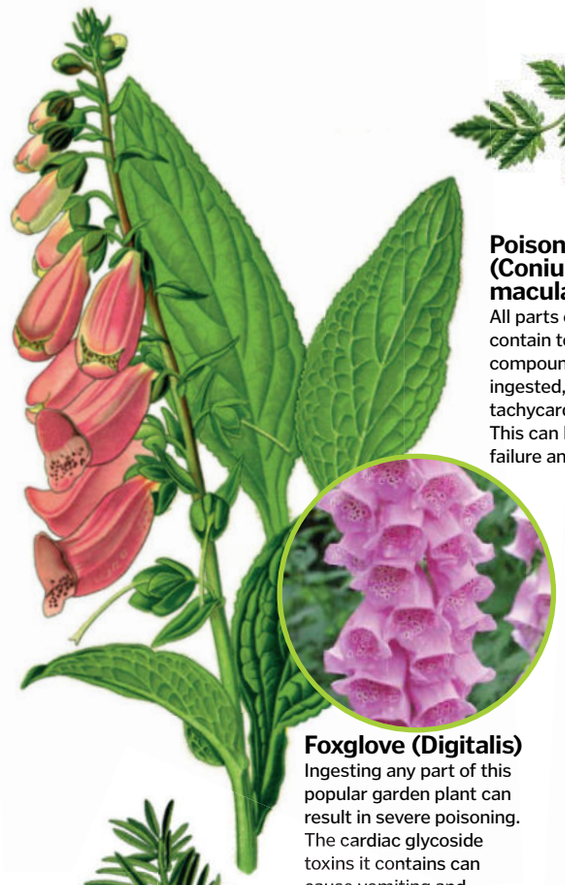
They may look harmless, but some species of flora can be fatal

There are lots of delicious and nutritious plants growing in nature, but there are also some that you should definitely keep off your plate. Even the most tasty-looking berries or succulent leaves can contain deadly poisons, while other plants are even harmful just to touch. It is thought that these poisonous plants evolved to contain their lethal toxins as a form of self-defence, poisoning the animals and humans who dare to eat or touch them to stop them from coming back for more. However, some plants affect animals and humans in different ways. For example, it takes just four castor seeds to kill a human, but 80 to kill a duck.

To make matters even more confusing, it is sometimes the case that only part of the plant is poisonous. For example, the stalks of rhubarb plants are great in a crumble, but eating the leaves, which contain oxalic acid, can cause nausea and vomiting. In other cases, toxic plants can actually benefit your health, as it has been discovered that the poisonous taxane alkaloids found in Yew trees contain chemicals that can be used to stop cancer cells from forming. Don't go munching on its leaves though, as you'll be left feeling rather unwell.

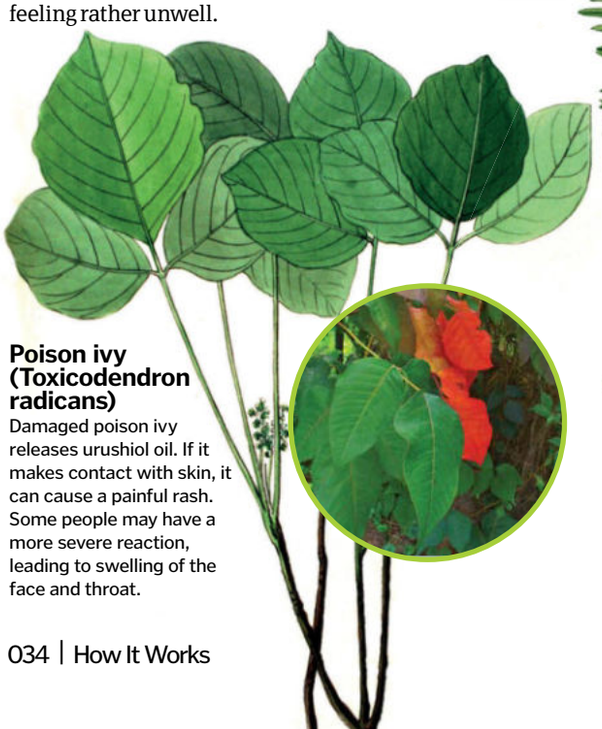


Poison hemlock (Conium maculatum)
All parts of poison hemlock contain toxic alkaloid compounds that, when ingested, can cause seizures, tachycardia and paralysis. This can lead to respiratory failure and ultimately death.



Foxglove (Digitalis)
Ingesting any part of this popular garden plant can result in severe poisoning. The cardiac glycoside toxins it contains can cause vomiting and diarrhoea, and in severe cases, visual distortion and heart problems.

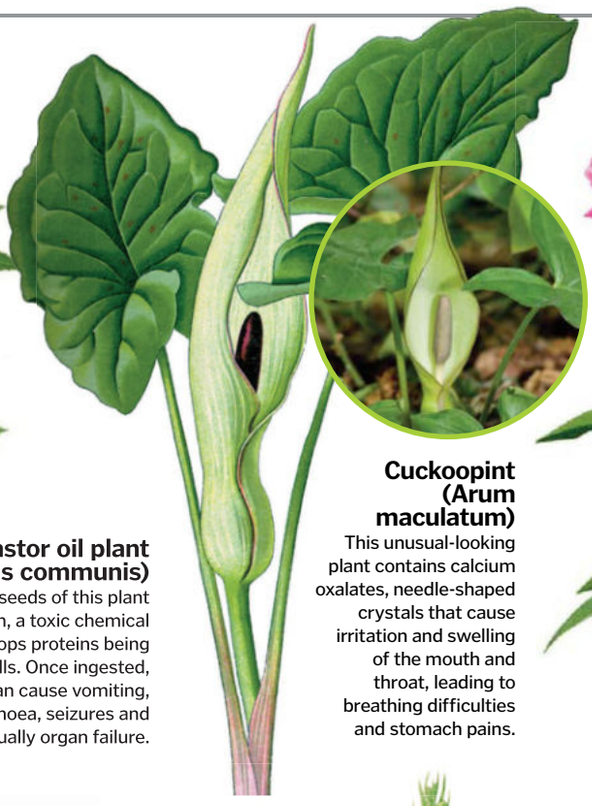
Golden chain (Laburnum)
Laburnum seeds are carried in pods, which look like pea pods, but shouldn't be eaten. The plant contains the poisonous alkaloid cytisine, which can be deadly in large doses.



Poison ivy (Toxicodendron radicans)
Damaged poison ivy releases urushiol oil. If it makes contact with skin, it can cause a painful rash. Some people may have a more severe reaction, leading to swelling of the face and throat.

Yew (Taxus)
Highly poisonous taxane alkaloids can be found in all but the flesh of the berries of this evergreen tree. Once ingested, there are sometimes no symptoms until the victim collapses and dies.

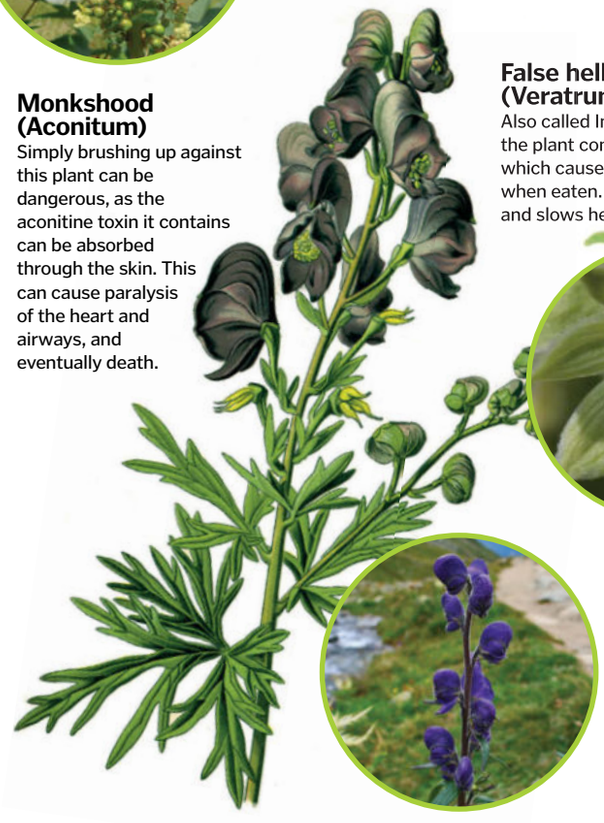
Castor oil plant (Ricinus communis)
The seeds of this plant contain ricin, a toxic chemical that stops proteins being made in cells. Once ingested, they can cause vomiting, diarrhoea, seizures and eventually organ failure.



Cuckoopint (Arum maculatum)
This unusual-looking plant contains calcium oxalates, needle-shaped crystals that cause irritation and swelling of the mouth and throat, leading to breathing difficulties and stomach pains.

Oleander (Nerium oleander)
This ornamental, evergreen shrub contains cardiac glycoside, which can prove fatal if ingested directly or if food has come into contact with the plant, and it can irritate the skin when touched.

Monkshood (Aconitum)
Simply brushing up against this plant can be dangerous, as the aconitine toxin it contains can be absorbed through the skin. This can cause paralysis of the heart and airways, and eventually death.



False hellebore (Veratrum viride)
Also called Indian poke, all parts of the plant contain steroidal alkaloids, which cause nausea and vomiting when eaten. It lowers blood pressure and slows heart rate.

Deadly nightshade (Atropa belladonna)
Its ripe berries may look appetising, but eating just two is enough to kill a child. The plant contains tropane alkaloids, which cause hallucinations and attack the nervous system.

When gardening, wear gloves to prevent dangerous plants from coming into contact with your skin

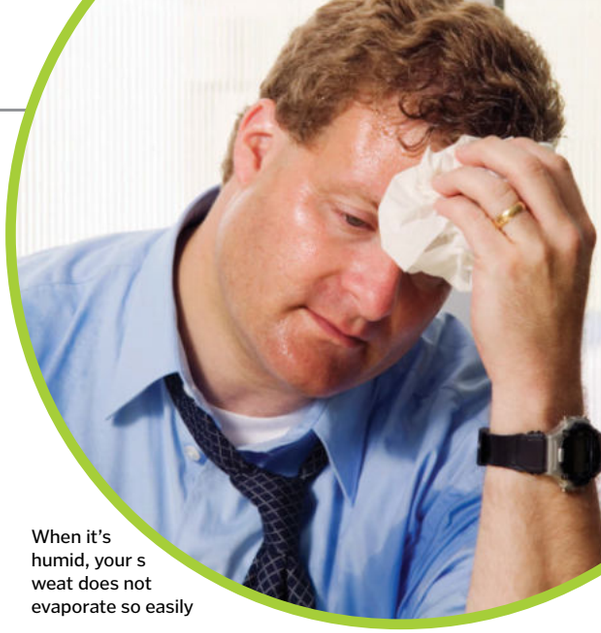
How to avoid poisonous plants

When outdoors, it is always best to be cautious around unfamiliar plants, and avoid touching or eating them unless you know they are safe. If you do have a reaction or become unwell after touching or ingesting a plant, visit a doctor straight away and take a piece of the plant with you. This will help them to identify it and determine the best cause of treatment. For many poisonous plants, there is no antidote available, but if caught early enough, the symptoms can usually be treated to avoid serious health problems or death.

What is humidity?

Discover the cause of uncomfortable, muggy weather that leaves you sweating

The air around you contains water in the form of a gas called water vapour, and the amount of vapour it contains is known as its humidity. If you have ever visited somewhere with a tropical climate then you may have experienced humid, muggy air, which can often leave you feeling uncomfortably hot. This is because the air around you is saturated, and cannot hold any more water vapour, so the sweat from your skin cannot evaporate to cool you down. Humidity can actually also affect you in cool climates, as the water vapour in the air conducts the cold temperature onto your skin, making you feel colder.



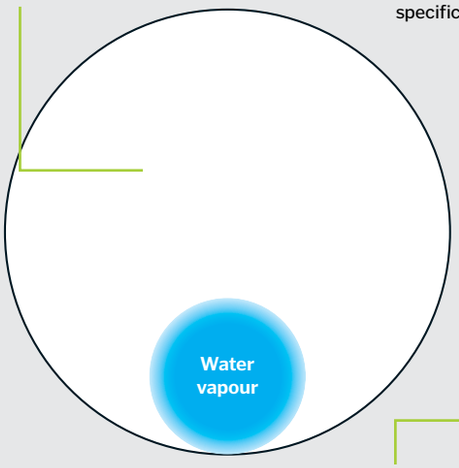
When it's humid, your s weat does not evaporate so easily

Calculating humidity

How does air temperature affect the relative humidity?

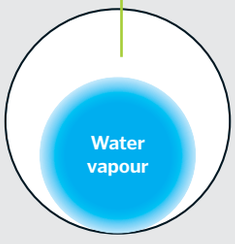
Warm air
Warmer air can carry more water vapour than cooler air because it has more energy to evaporate water into vapour.

Relative humidity
Relative humidity measures how much water vapour is in the air compared to the maximum that there could be at that specific temperature.



20% RELATIVE HUMIDITY

Cool air
The same amount of water vapour results in higher percentages of relative humidity in cooler air than it does in warmer air.



50% RELATIVE HUMIDITY

Dew can form on the ground when the surrounding air becomes saturated with water vapour

Dew point
When the air cannot hold any more water vapour, it will start to condense as dew.

Saturation
When the air is carrying as much water vapour as it can hold, it is described as 'saturated'.

100% RELATIVE HUMIDITY

What are whiskers?

Find out how these specialised hairs help animals to sense their surroundings

Whiskers are long, thick hairs that extend a mammal's sense of touch beyond the surface of their skin. They are connected directly to the nervous system via sensory organs called proprioceptors at the base of the hair, which send information about the body's position and movement to the brain. When an animal's whisker comes into contact with an object or is disturbed by the flow of air or water, the movement stimulates the proprioceptor, which relays this sensory information to the brain. Whiskers can provide the animal with details about the position, shape, size and texture of objects around them, as well as wind or water currents.

Cats use their whiskers to gauge distances when making leaps, while seals use theirs to catch prey by detecting the motion of water trails left by fish. Many rodent species use a technique called whisking, where they sweep their whiskers back and forth to help map their environment. Research suggests that whiskers first evolved to help early mammals navigate in the dark, giving them an advantage over reptiles.

A cat's whiskers are roughly equal to the width of its body, so they help it decide whether it can fit through a gap

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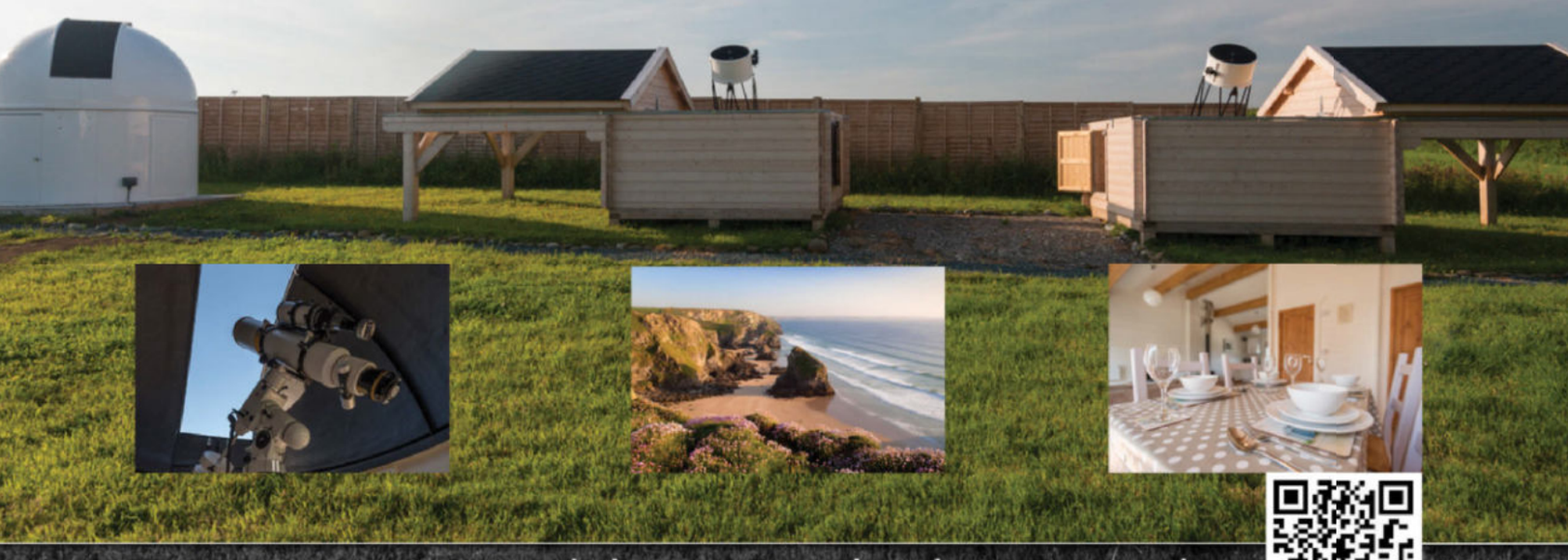

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THE FUTURE OF TEACHING

WHAT WILL SCHOOLS BE LIKE IN 2050?

The modern-day classroom isn't really all that different from a Victorian classroom. The teacher still stands at the front, with the children facing them, answering questions and taking hand-written notes. While there isn't a cane, and we've swapped squeaky chalk for marker pens, the format hasn't really evolved.

It's strange when you consider the advancements that we've made in the same amount of time: we've landed on the Moon, unravelled the human genome and created super-computers you carry in your pocket. So why is education stuck in the 20th century?

In some schools, it isn't; advancements in teaching, communication and technology have totally changed the working environments of students around the world, and the future only holds more progress. Looking closer at that modern day classroom reveals some details you may have missed at the first pass. Those hand-written notes might be taken on an iPad with a stylus, with the handwriting converted into typed text and the finished document saved to the 'cloud'. The board is interactive, and can display websites, videos and more that the teacher can control with a smart remote.

In fact, while the basic format of teaching may remain largely unchanged, technology has improved how kids learn, what they learn, and how they are taught. Textbooks are, of course, still a big part of the school experience, but increasingly e-books and online research are being used in place of the traditional tomes. In some schools, students are loaned iPads or other tablets, loaded with their entire reading list for the year. Rather than straining their spines by carrying huge backpacks, pupils only need one device. Even better, they can make helpful notes on the pages, or highlight useful sections, without being charged for defacing the book.

Of course, these books can also include links to websites that aid learning. Digital pages can contain useful information for additional study or homework, or can even take students to online tests. The teacher can then check in on who has taken the test, how they scored, and get more information about each pupil, including how long they spent working on each question.

The internet has become a valuable teaching resource and is regularly used in the classroom. Rather than formal videos recorded in the days of VHS, teachers can quickly find useful resources and play them to the class. Not only is this more engaging than a video that's decades old, it can also prompt further discussion.

Technological advancements have changed the way teachers work, too. More and more, students are being encouraged to work in small groups and foster interaction, with technology as an enabler. Learning spaces are being redesigned to reflect this, and teachers' roles are slowly changing to a more passive role.

And as technology becomes more and more accessible, this will only increase. Tech like 3D printing will allow students and teachers alike to create teaching materials within minutes. 3D modelling lessons will be able to go from the design to the prototyping stage within a few hours, while lessons about biology will see teachers printing out 3D models of ancient animal skulls to pass around the class. Cloud computing will eradicate excuses like "the dog ate my homework", and give classmates a chance to discuss their work at home, using teacher-controller chatrooms that allow them to collaborate on projects. Gaming will increasingly be used to teach, and eye-tracking will help teachers analyse what works best in the classroom, and what is failing to grab attention.

Of course, as teaching changes, so will the curriculum. For example, as computing skills are becoming more important in this digital age, many students are learning how to program. In the UK, pupils as young as five are being taught how to code, with simple games showing them the basics.

The idea of every student having a tablet won't seem odd in ten years

TABLETS OVER TEXTBOOKS

In the coming years, the idea of carrying around piles and piles of heavy books for each school day will likely be a thing of the past. Whether it's schools providing their pupils with tablets, or students bringing in their own computer devices, the future of the textbook is clearly in a touchscreen display. A single tablet can hold an entire year's worth of learning materials, as well as providing students with interactive tests, videos and apps, controlled by the school. In some schools in the US, this is already happening, and it's undoubtedly the first step in a teaching revolution.

Games will be used as part of coding lessons, helping children to have fun while they learn

GAMING AND LEARNING

Many teachers and parents assume video games are unnecessarily violent and highly addictive, and without educational merit. But in recent years games have started making their way into the classroom as learning materials. Games like Minecraft, which now has a dedicated Education Edition, can teach children through play. And kids who usually go home and spend hours of their free time on games like this are enjoying learning more than ever. Using games in the classroom will only increase as coding lessons become more commonplace in the near future.

Virtual reality will let students take trips through history and into space

VIRTUAL REALITY LESSONS

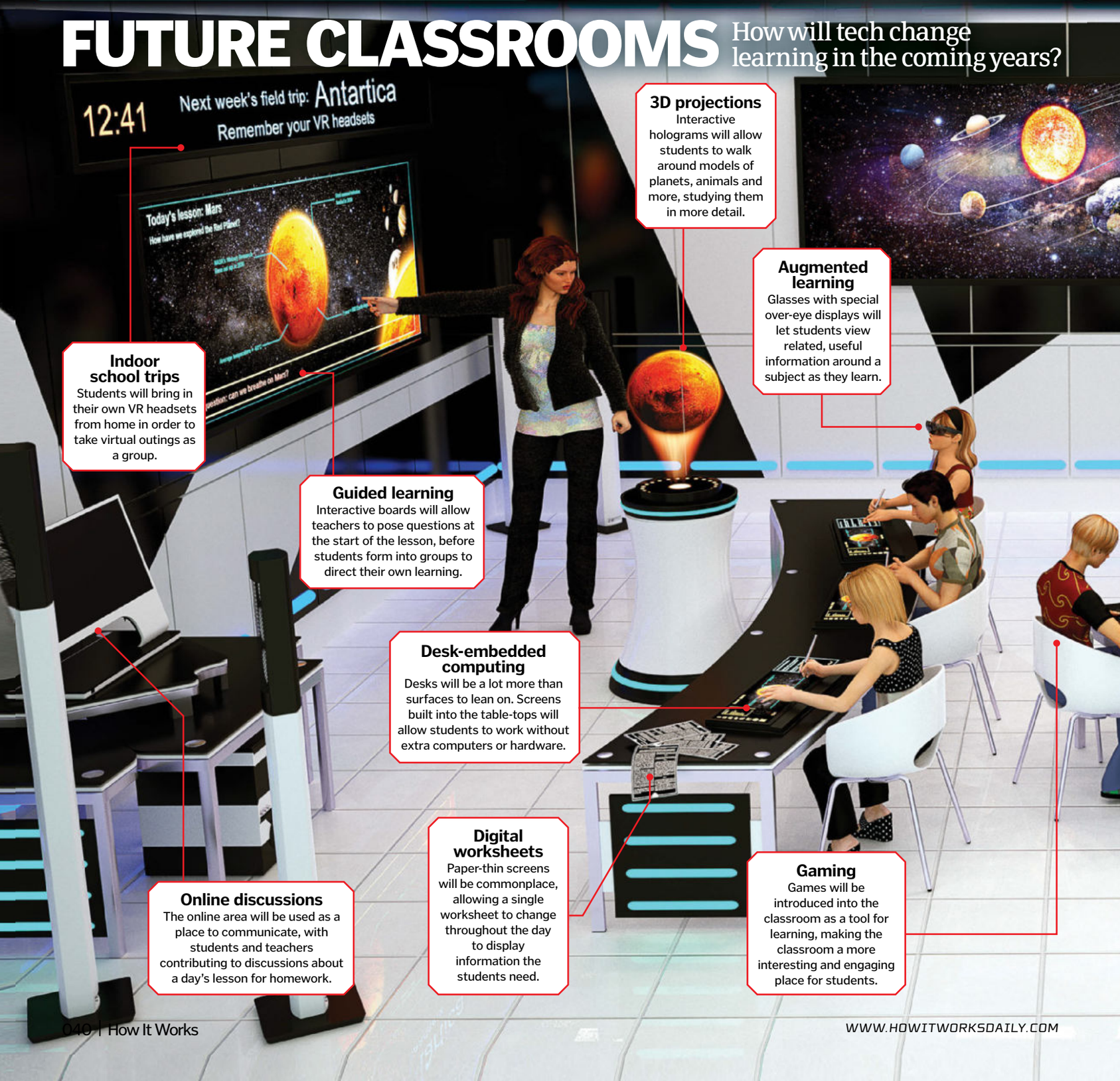
Soon, classes won't need to leave the school to take a field trip. Virtual reality headsets will allow students to journey across the world, and even dive beneath the waves or float through space, without ever leaving the room. As this technology becomes more affordable and software developers begin to create virtual learning spaces, lessons will become more engaging and immersive than ever before. Pupils could soon find themselves learning about volcanoes from the edge of Mount Etna, exploring ancient dig sites in Egypt, or even taking a trip through the human body to study anatomy.

Desk-embedded computing

Augmented learning

FUTURE CLASSROOMS

How will tech change learning in the coming years?



Indoor school trips
Students will bring in their own VR headsets from home in order to take virtual outings as a group.

3D projections
Interactive holograms will allow students to walk around models of planets, animals and more, studying them in more detail.

Augmented learning
Glasses with special over-eye displays will let students view related, useful information around a subject as they learn.

Guided learning
Interactive boards will allow teachers to pose questions at the start of the lesson, before students form into groups to direct their own learning.

Desk-embedded computing
Desks will be a lot more than surfaces to lean on. Screens built into the table-tops will allow students to work without extra computers or hardware.

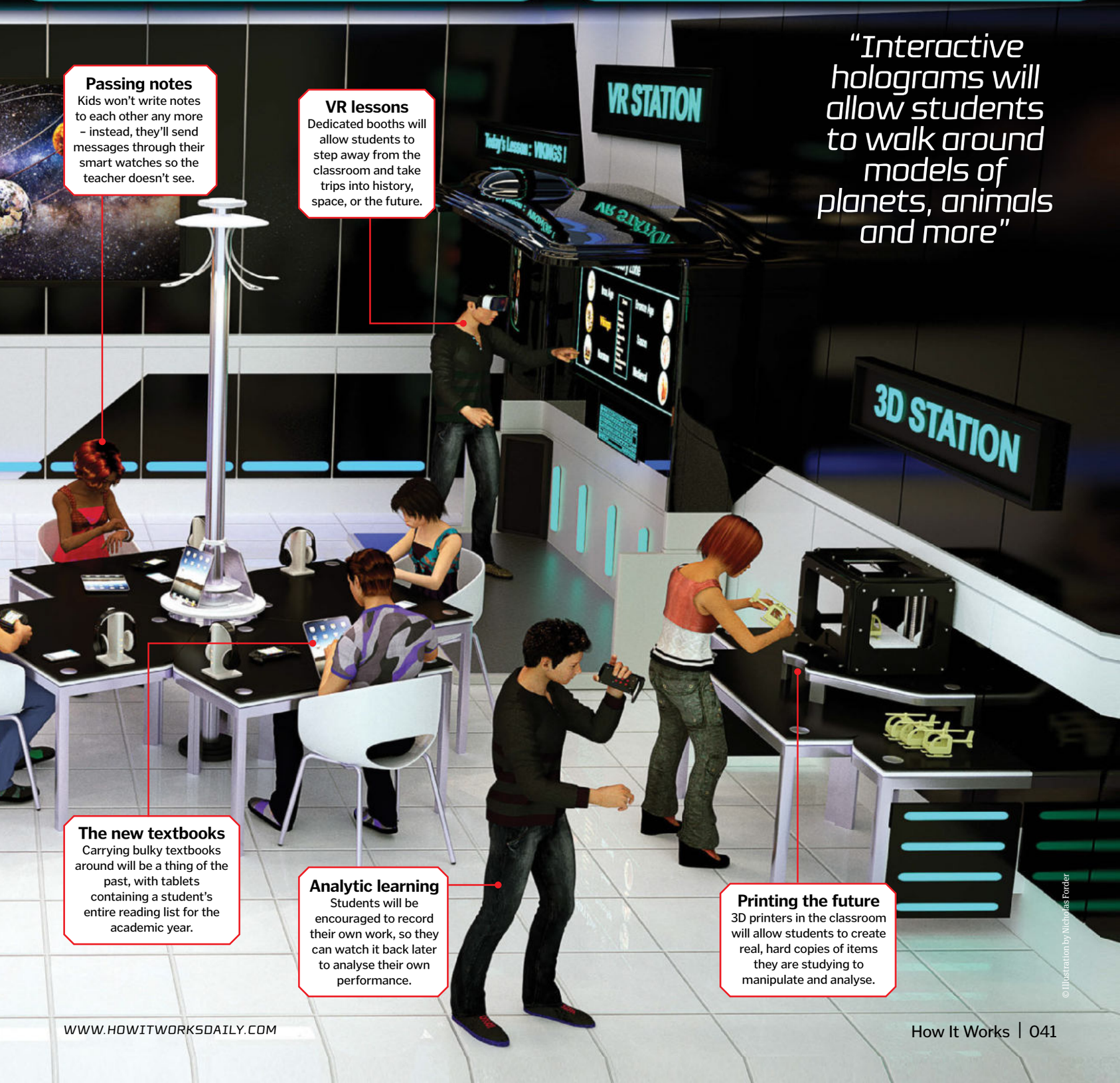
Digital worksheets
Paper-thin screens will be commonplace, allowing a single worksheet to change throughout the day to display information the students need.

Online discussions
The online area will be used as a place to communicate, with students and teachers contributing to discussions about a day's lesson for homework.

Gaming
Games will be introduced into the classroom as a tool for learning, making the classroom a more interesting and engaging place for students.

Passing notes

VR lessons



"*Interactive holograms will allow students to walk around models of planets, animals and more*"

Passing notes
Kids won't write notes to each other any more – instead, they'll send messages through their smart watches so the teacher doesn't see.

VR lessons
Dedicated booths will allow students to step away from the classroom and take trips into history, space, or the future.

The new textbooks
Carrying bulky textbooks around will be a thing of the past, with tablets containing a student's entire reading list for the academic year.

Analytic learning
Students will be encouraged to record their own work, so they can watch it back later to analyse their own performance.

Printing the future
3D printers in the classroom will allow students to create real, hard copies of items they are studying to manipulate and analyse.

Pet tech

How exactly do these gadgets help to keep our furry friends entertained?

Approximately 40 per cent of UK households have pets, and with more of us leading busy lifestyles, it's not always possible to give our animal pals as much attention as we, and they, would like. However, thanks to technology we can now keep an eye on our pets and make sure they are entertained even when they're home alone. From automatic ball launchers to Wi-Fi treat dispensers, there are now many gadgets on the market to help keep our pets happy and healthy.

The growing pet tech market is an example of the 'internet of things', the development of everyday items that feature network connectivity. Gadgets that feature internet access via Wi-Fi or mobile networks provide owners with the ability to easily check in on and interact with their pets via their smartphones. This way, you can remotely keep an eye on Fido and give him treats even while you're busy in the office!

How the iFetch works

The perfect toy for your pooch to play with when you're away

On-demand play
The device powers on automatically when a ball is dropped into the funnel, and goes into power-saving mode after launch.

Hours of fun
On a fully charged set of batteries, the iFetch can keep throwing balls for around 30 hours – enough to tire out even the most playful of puppies!

Go long!
The iFetch's shooting distance can be adjusted to three, six or nine metres, depending on how much space you have.

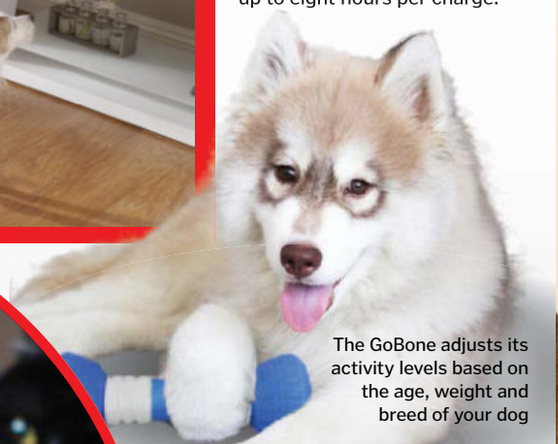
Launch system
Rapidly spinning wheels within the iFetch accelerate the balls and shoot them out of the funnel.

Petzi

This camera enables you to keep an eye on your pet using the accompanying smartphone app. The wide-angle lens provides you with a fantastic view of your furry friend, and treats can even be launched from the unit at the simple touch of a button.

GoBone

A treat-filled plastic bone on wheels that moves around to encourage your dog to play. It provides mental and physical stimulation as pups chase, chew, squeak and eat food from it for up to eight hours per charge.



The GoBone adjusts its activity levels based on the age, weight and breed of your dog

PetChatz

This interactive system connects to your home Wi-Fi network, so you are able to hold video calls with your pets through the companion app. The wall unit can also dispense treats, and a special PawCall button on the floor even means that your pet can call you!

The PetChatz enables you to check in with your pet from afar

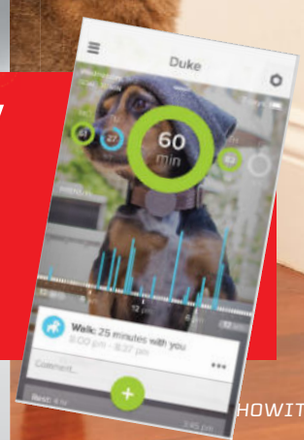
Shru

This egg-like toy can help to keep your cat active and entertained all day long. Designed to look and act like a feline's prey, it autonomously darts around, keeping your kitty on its toes (or paws). You can also modify the Shru's behaviour by connecting the gadget to your computer via USB.

The Shru mimics the motion and even sounds of a small rodent

Whistle Activity Monitor

A fitness tracker for your dog, Whistle helps keep track of your pet's activity levels and health. Attaching the small disc to your dog's collar enables you to monitor its daily activity through the Whistle app on your phone.



Planet Earth Education

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How does Astronomy affect our everyday life?

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- **The Moon causes eclipses whilst its phasing determines the date for Easter Sunday.**
- **Constellations can be used for navigation.**
- **Astronomy is one of the oldest sciences.**

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We only make science puns periodically

Inside the HTC Vive

Take a closer look at the world of virtual reality

Virtual reality (VR) simply wouldn't be possible without a bucket load of tech being able to fit into a small, portable headset. The HTC Vive is a marvel of engineering, packing 32 sensors into the headset itself – along with a front-facing camera – and 24 more in each of the two controller handsets. These sensors pair with the two base stations to record all kinds of information, including where you are moving to, how fast you're going, and which direction you're facing.

The base stations are small cubes facing into the playing area. They fire invisible infrared beams into the area, which are picked up by the sensors on the headset to detect the location of the HTC Vive headset (and the controllers) in real-time. All of these sensors combine to make the images you see feel as real as possible as you turn your head and walk around.

But that makes the whole thing sound very straightforward. In fact, the Vive also needs to be connected to a powerful computer, which can process all the data from all of the sensors, and then instantaneously send the video images into the two lenses that sit right in front of your eyes. As you interact with the world around you, the computer completes millions of calculations every second and gives you instant feedback within the game that you're playing. The two displays in the headset offer a 110-degree field of view, with each one's 1080 x 1200 resolution giving you better-than-HD visuals. It's an incredible piece of tech, and the experiences you can have with it are stunning.

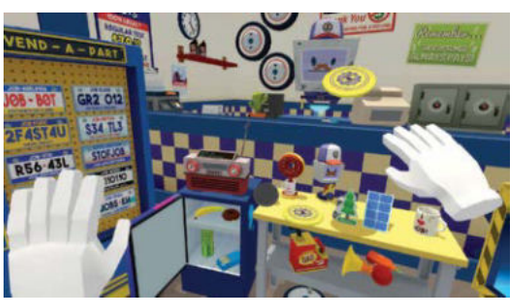
The HTC Vive will set you back $800 in the US or £770 in the UK

Light gasket
This rubber shape slides over the two lenses to stop light from the displays leaking out the sides and disrupting your view.

Lenses
The lenses are convex to make the image appear natural to your eye, and concentric circles assist with focus.

IPD System
The Interpupillary Distance System changes the distance between the two lenses to make viewing more comfortable.

AMOLED displays
These two displays each offer a resolution of 1080 x 1200, making the total resolution of your game 2160 x 1080.



Games will often simulate your hands in 3D space, so you can interact with objects naturally

HTC Vive teardown

How does the VR headset track every tiny movement?

Proximity sensor
This tiny sensor on the inside of the headset can detect when you take the Vive off your face, so it can turn off the displays.

Head strap
The adjustable head strap keeps the Vive securely on your face, and directs the cables from the headset over your head.

Motherboard
This motherboard features 18 different chips, which the headset uses to translate data to the computer from the sensors.

Camera
This camera sits on the front of the Vive and sends data back to the computer about items in the player's vicinity.

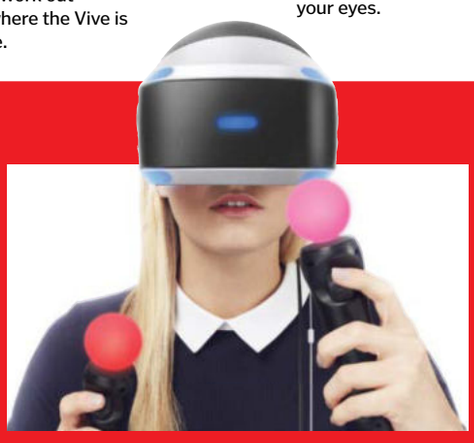
Sensors
32 sensors in the headset pick up the infrared beams emitted by the base stations to work out precisely where the Vive is in 3D space.

Eye-relief cog
You can turn this cog, which sits on the side of the headset, to move the lenses closer or further from your eyes.

The HTC Vive rivals

Probably the most famous rival to the Vive is the Oculus Rift, which features integrated audio, comes with an Xbox One game controller, and also has its own motion controllers.

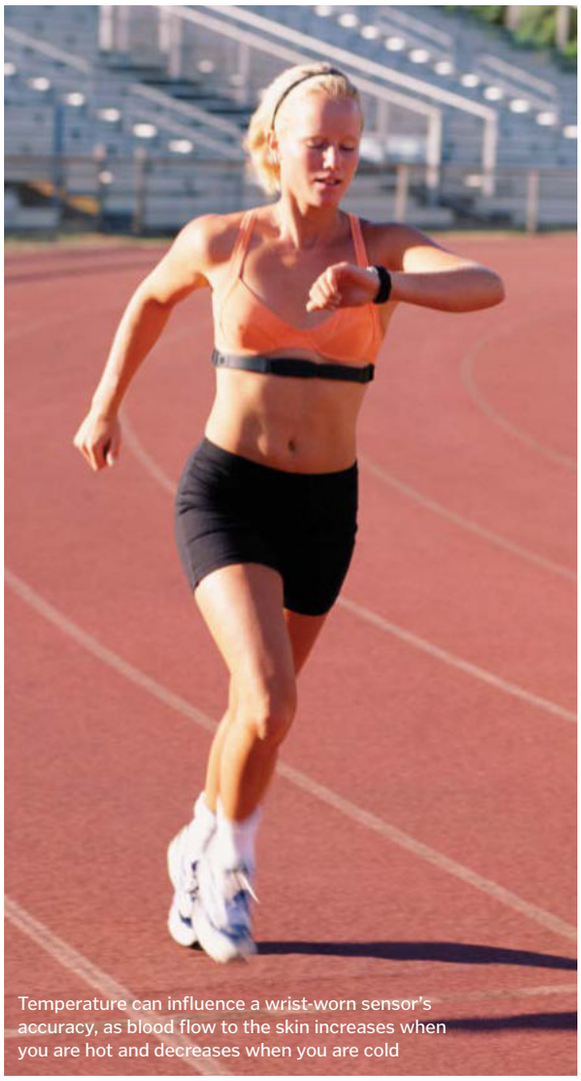
The Samsung Gear VR headset is really just that – a headset that your Samsung phone can slot into to give you a cheap but quite effective VR experience. It doesn't compare to the Vive, though.



Sony's entry into the VR market is PlayStation VR, which hooks up to the PlayStation 4. It's more affordable than the Vive or Oculus Rift, making it an attractive choice for those on more of a budget.

Heart rate monitors

How these fitness gadgets use light to detect your pulse



Temperature can influence a wrist-worn sensor's accuracy, as blood flow to the skin increases when you are hot and decreases when you are cold

1. Flashing light
A green LED flashes hundreds of times every second, while a light sensor detects how much is reflected.

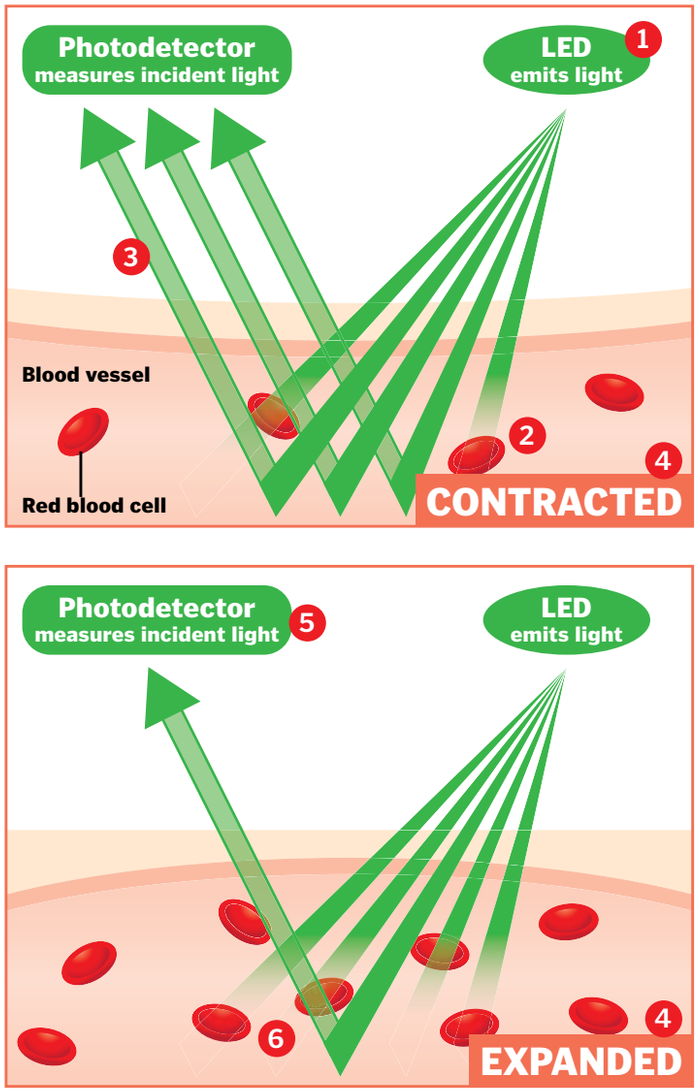
2. Simple principle
Red blood cells reflect red light and absorb green light.

3. Reflection
Some of the light that isn't absorbed is reflected back to the light sensor.

4. Blood flow indicator
Your blood flow is highest when your heart pumps and arteries expand, and is reduced between beats when arteries contract.

5. Change in light
By detecting fluctuations in the amount of light being absorbed, the monitor can calculate how many times your heart beats each minute.

6. Absorption
The green light travels through the skin and some is absorbed by the red blood cells. When your heart beats, blood flow is greater, so absorption increases.



How binoculars focus

How turning a dial makes a blurry view crystal clear

Whether you use binoculars for astronomy or bird-watching, being able to focus on what you're observing is crucial. To view objects at a range of distances, most binoculars have a central wheel that can be adjusted to bring light rays from different distances into focus.

Binoculars contain two pairs of convex lenses: the objective and eyepiece lenses. The objective lenses pick up light rays from objects in the distance and bend them inwards so they converge to produce a small image within the binoculars. The second set, known as eyepiece lenses, act like a magnifying glass to enlarge this image for you to view. Turning the focusing wheel changes the distance between the objective and eyepiece lenses. This helps adjust the path of light to create a sharp, focused image.

Some binoculars offer the ability to focus each of the two barrels individually. This is called diopter adjustment and helps fine-tune each eyepiece, a useful feature if one of your eyes is stronger than the other. Alternatively, auto-focusing binoculars are fixed by the manufacturer for mid- to long-range viewing, and rely on your eyes' natural ability to change focus.

The focusing wheel alters the distance between the binoculars' lenses to keep your view sharp

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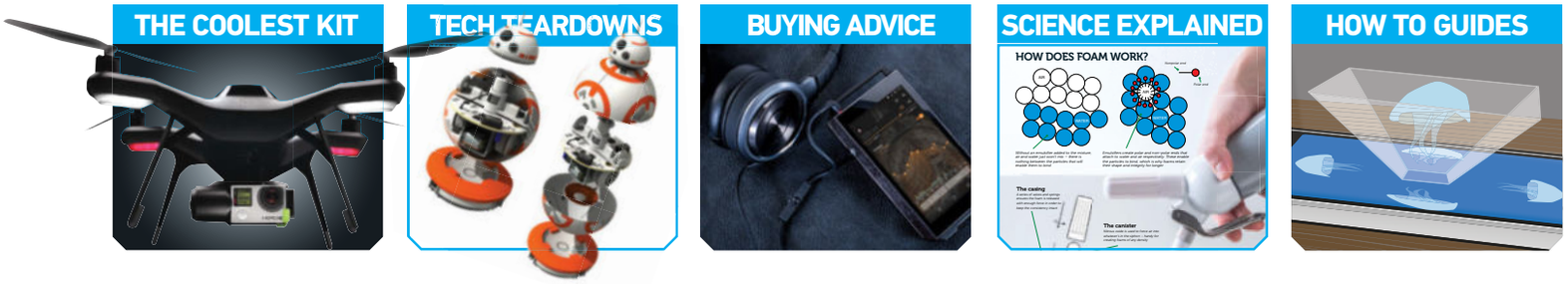

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EXTREME WEATHER SURVIVAL

The science and tech that can help you make it through the eye of a storm

From lightning strikes and flash floods to wildfires and tornadoes, there's a lot that nature can throw at us in the form of extreme weather. As global temperatures rise due to climate change, these devastating events are occurring more frequently and more severely. To protect lives and infrastructure, communities need as much warning as possible, giving them enough time to prepare emergency supplies and find shelter. In order for that to happen, forecasters need to be able to accurately predict the intensity and path of storms, something that new technology is helping to make possible.

One of the most important breakthroughs has been improved radar technology, which can measure the location, intensity, direction, speed and type of precipitation. It works by emitting radio waves that bounce off particles in the atmosphere, such as raindrops, and measuring how long it takes for the radio waves to return. Currently radar can only scan small areas at a time, meaning it takes four to six minutes to get a full picture, but in the future, a new phased-array radar could send out multiple waves simultaneously, scanning the entire atmosphere in less than a minute. This will enable forecasters to spot rapid weather changes sooner, extending the warning time to more than 18 minutes.

Further research into extreme weather prediction is also being done with the help of the world's largest hurricane simulator at the University of Miami. The 172,000-litre tank produces rolling waves and 251-kilometre-per-hour winds to help scientists better understand the intensity of storms. It will provide useful information for building stronger structures.

The University of Miami's hurricane simulator can simulate Category 5 hurricane conditions

LIGHTNING STORMS

Thunderbolts and lightning can be very, very frightening

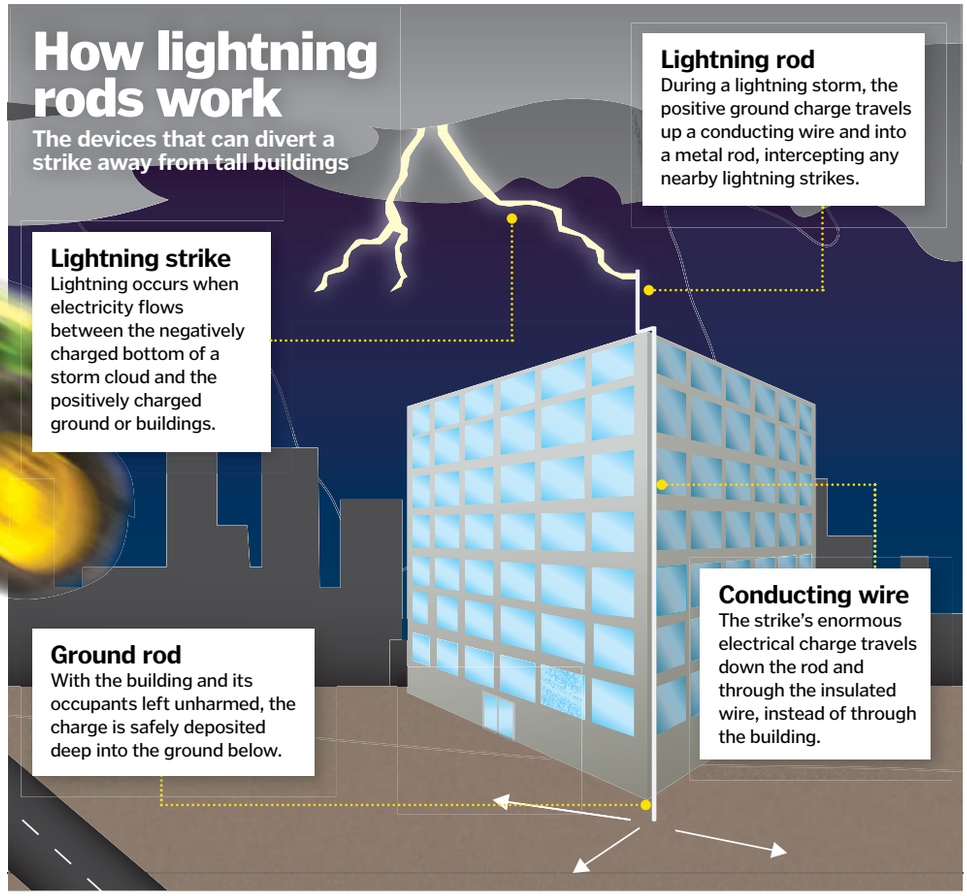
On average, your chances of being killed by lightning are 300,000 to one, but if you are one of the unlucky ones then you can expect a huge 300 kilovolts of electricity to pass through your body. Reaching temperatures of 27,760 degrees Celsius, the strike will cause severe skin burns, and is likely to cook your internal organs as well as stop your heart. To avoid such a scorching fate, the best course of action to take when a lightning storm approaches is to find shelter inside a sturdy building or hard-topped vehicle, and avoid contact with metal and water, which can transfer the electrical charge to your body. If you are stuck outside, crouch down to make yourself as small as possible, and keep only your feet touching the ground. When lightning strikes, the electric charge can sometimes radiate outwards through the ground, so by keeping as little of your body in contact with it as possible, you reduce the risk of an electric shock.

DID YOU KNOW?

Lightning rods were invented by US Founding Father Benjamin Franklin

How lightning rods work

The devices that can divert a strike away from tall buildings



Lightning rod
During a lightning storm, the positive ground charge travels up a conducting wire and into a metal rod, intercepting any nearby lightning strikes.

Lightning strike
Lightning occurs when electricity flows between the negatively charged bottom of a storm cloud and the positively charged ground or buildings.

Conducting wire
The strike's enormous electrical charge travels down the rod and through the insulated wire, instead of through the building.

Ground rod
With the building and its occupants left unharmed, the charge is safely deposited deep into the ground below.

WHEN LIGHTNING STRIKES

WHAT NOT TO DO DURING A LIGHTNING STORM

Play golf
Metal objects such as golf clubs are good conductors of electricity.

Stand under a tree
Tall objects are more likely to be struck, and the current could jump to you.

Use electric appliances
Unplug all appliances as lightning can cause surges.

Take a bath
Metal pipes will conduct electricity if lightning strikes your house.

Swim outdoors
Water conducts electricity when lightning strikes, so avoid electrocution.

64% of deaths caused by lightning between 2006 and 2013 in the US occurred while people were participating in leisure activities, such as fishing or playing golf

BLIZZARDS

When a blizzard struck the eastern United States in January 2016, the roofs of several buildings caved in under the weight of 91 centimetres of snow, transport systems were thrown into chaos, and more than 36 people lost their lives in the treacherous conditions. These extreme snowstorms occur when large amounts of snow (either falling or already on the ground) is blown by winds in excess of 56 kilometres per hour, reducing visibility to less than 0.4 kilometres. This makes it incredibly dangerous to travel by car, with road accidents a common cause of blizzard deaths. The combination of cold temperatures and strong winds can also result in low wind chill levels of -50 degrees Celsius, putting you at risk of frostbite and hypothermia as your body temperature drops. If you do find yourself caught in a blizzard, then your best chance of survival is to not travel, stay indoors, and keep as warm as possible.

Blizzards result in very poor visibility, making driving incredibly dangerous

FLOODING

How can we prevent and protect against the hazards of floods?

DID YOU KNOW?
It takes 90 minutes to close all ten Thames Barrier gates

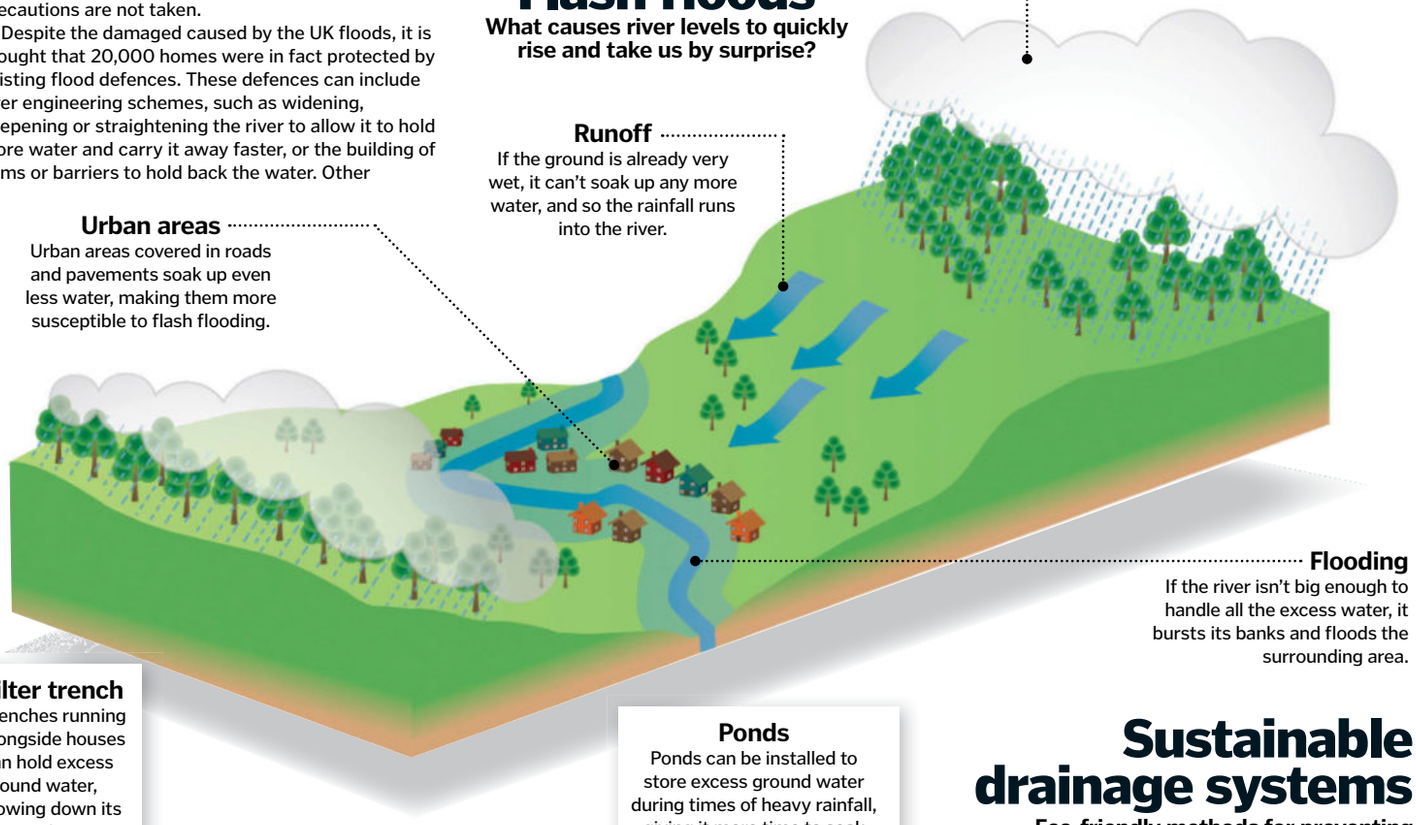

Flash flooding gives people very little time to prepare for the oncoming water

When storms bring heavy rainfall, rivers can struggle to contain the deluge of water, causing the banks to burst and the surrounding landscape to flood. In December 2015, a series of storms caused widespread flooding across the UK, with around 16,000 homes, acres of farmland and transport and communications infrastructure damaged by the water. Luckily, in this instance, no lives were lost, but fast-moving and murky flood waters can present a variety of health hazards if proper precautions are not taken.

Despite the damaged caused by the UK floods, it is thought that 20,000 homes were in fact protected by existing flood defences. These defences can include river engineering schemes, such as widening, deepening or straightening the river to allow it to hold more water and carry it away faster, or the building of dams or barriers to hold back the water. Other techniques include the creation of sustainable drainage systems, designed to help heavy rainfall soak into the ground instead of flowing straight into rivers. Planting vegetation, using permeable paving materials and creating floodplains – areas intentionally designed to flood – can all help to prevent rising river levels and protect those living along the banks.

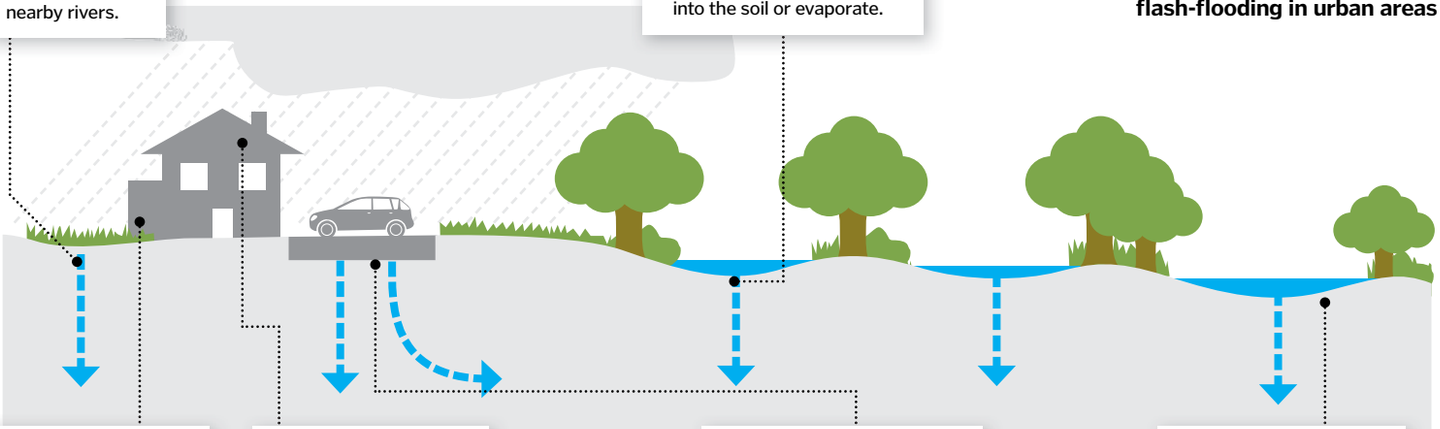
Flash floods

What causes river levels to quickly rise and take us by surprise?



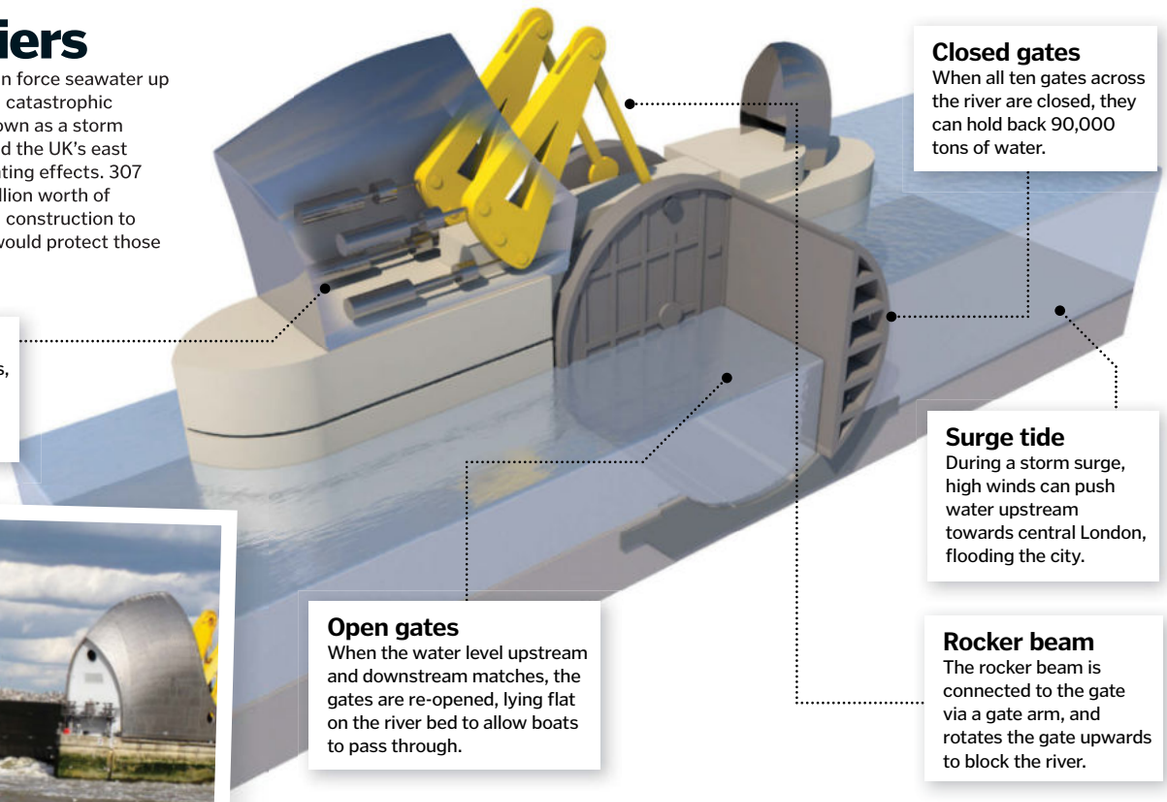
Sustainable drainage systems

Eco-friendly methods for preventing flash-flooding in urban areas



Flood barriers

During a storm, high winds can force seawater up rivers from the coast, causing catastrophic flooding upstream. This is known as a storm surge, and in 1953, London and the UK's east coast experienced its devastating effects. 307 people were killed and £1.2 billion worth of damage was done, prompting construction to begin on a flood barrier that would protect those living along the Thames.



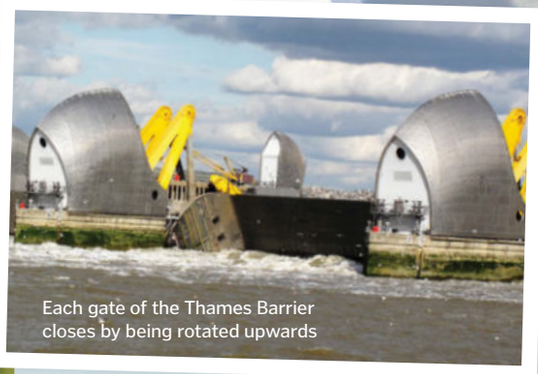
Hydraulic cylinders
Before a storm surge occurs, hydraulic cylinders in the steel-clad shell next to the gate lift the rocker beam.

Closed gates
When all ten gates across the river are closed, they can hold back 90,000 tons of water.

Surge tide
During a storm surge, high winds can push water upstream towards central London, flooding the city.

Open gates
When the water level upstream and downstream matches, the gates are re-opened, lying flat on the river bed to allow boats to pass through.

Rocker beam
The rocker beam is connected to the gate via a gate arm, and rotates the gate upwards to block the river.



Each gate of the Thames Barrier closes by being rotated upwards

Flood health hazards

The hidden dangers of travelling through flooded streets

Drowning
Regardless of your swimming ability, even slow-moving, shallow flood waters can be deadly, especially for small children.

Dangerous animals
Avoid any animals displaced by the flood and call the local authorities to handle them. Also be aware that flood water can attract disease-carrying mosquitos.

Electrocution
Water is capable of conducting electricity, so can pass the charge from fallen power lines onto anyone submerged.

Oil spills
Avoid gasoline and crude oil floating on the water as they are highly flammable and can be harmful to the skin or when breathing their vapours.

Wound infections
Any open wounds or rashes on the skin can become infected when exposed to dirty flood water, so ensure they are covered with a waterproof bandage.

Hidden hazards
Murky flood water can conceal sharp objects you could cut yourself on and holes you could fall into, so take extra care.

Trench foot
If your feet are submerged in water for a prolonged period of time, blood flow to the area becomes restricted, resulting in swelling and nerve damage.

Infectious diseases
Flood water can carry diseases such as E. coli, so avoid eating or drinking anything contaminated by it and wash your hands after touching it.

WILDFIRES

Make sure nothing stands in its way

When an area is experiencing a prolonged period of very hot, dry weather or drought, the risk of wildfires increases. These rampaging infernos engulf everything in their path and once they get going, are very hard to stop. In May 2016, over 5,600 square kilometres of Fort McMurray in Alberta, Canada was consumed by an enormous wildfire, forcing 88,000 people to abandon their homes. It is not known what started the flames, but there are several potential causes. Some wildfires are started naturally, by lightning strikes, volcanic eruptions, or simply the heat from the Sun. However, most are the result of human carelessness, such as cigarettes or campfires.

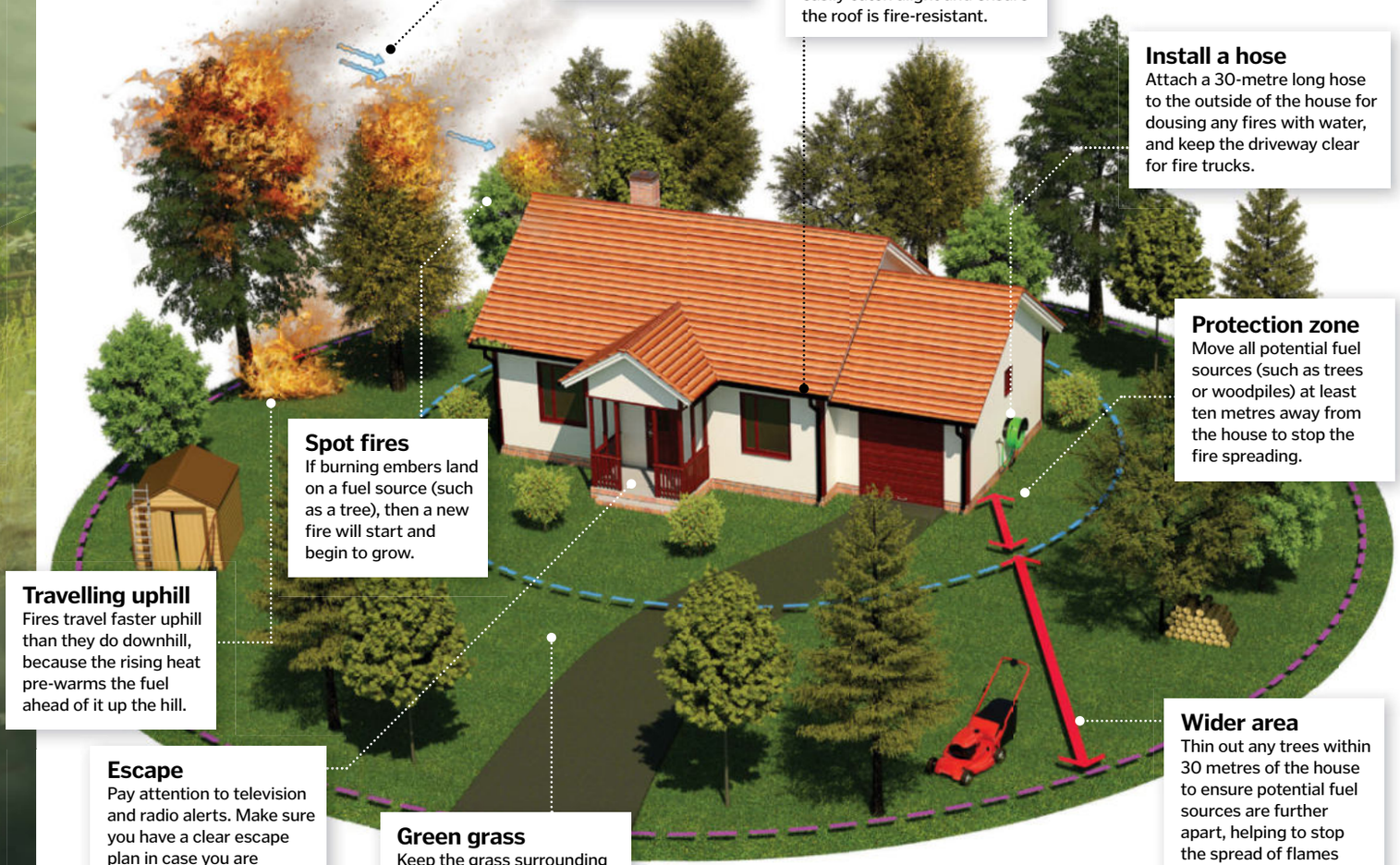
For a fire to burn, three things must be present; oxygen, heat and fuel, creating what's known as the fire triangle. The heat comes from an existing fire or the Sun, the oxygen is found in the surrounding air, and the fuel can be anything that burns easily. To stop the fire, one of these elements must be removed, and as not much can be done about the heat or air, the best option is to remove the fuel, clearing away flammable objects in the fire's path.

Trees, fields and even buildings act as fuel for a wildfire

Densely forested areas are particularly prone to wildfires as the flames can easily jump from tree to tree

Wildfire protection

How do wildfires spread and how can you stop them engulfing your house?



High winds
Wind feeds oxygen to the fire, keeping it alight, and can send burning embers flying through the air.

Clear the gutters
Keep the gutters and chimney clear of debris that could easily catch alight and ensure the roof is fire-resistant.

Install a hose
Attach a 30-metre long hose to the outside of the house for dousing any fires with water, and keep the driveway clear for fire trucks.

Protection zone
Move all potential fuel sources (such as trees or woodpiles) at least ten metres away from the house to stop the fire spreading.

Spot fires
If burning embers land on a fuel source (such as a tree), then a new fire will start and begin to grow.

Travelling uphill
Fires travel faster uphill than they do downhill, because the rising heat pre-warms the fuel ahead of it up the hill.

Escape
Pay attention to television and radio alerts. Make sure you have a clear escape plan in case you are ordered to evacuate.

Green grass
Keep the grass surrounding your house well-watered and healthy, so that it doesn't become dry fuel for fires.

Wider area
Thin out any trees within 30 metres of the house to ensure potential fuel sources are further apart, helping to stop the spread of flames from tree to tree.

TORNADOES

What should you do when a twister comes to town?

Stretching towards the ground from the base of angry thunderstorm clouds, tornadoes are whirling columns of air that can measure several kilometres across and whip up winds exceeding speeds of 400 kilometres per hour. As well as flattening anything in their path, they can also send debris flying through the air and even pick up and later drop people from great heights. Although the best course of action is to get out of their way, there often isn't much time to do so, as tornadoes can be very difficult to predict. When a three-kilometre-wide twister formed near Moore in Oklahoma, US, in May 2013, residents had just 16 minutes warning before 320-kilometre-per-hour winds struck their town, killing 24 people.

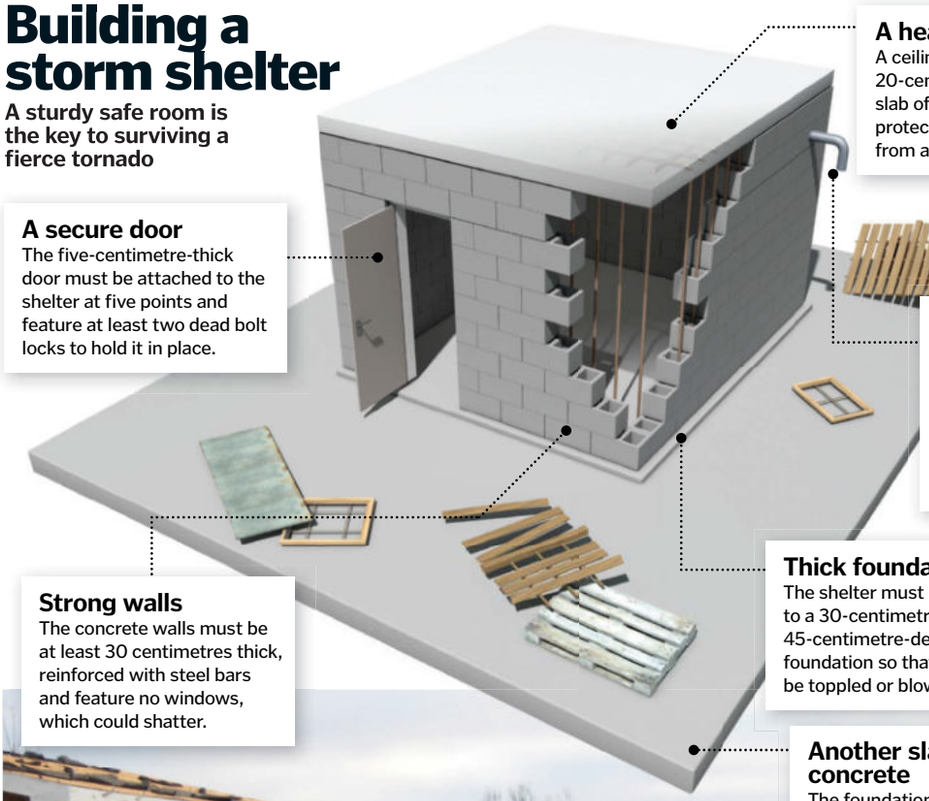
Although tornado forecasting is improving with the use of satellite data, radar systems and computer simulation software, the sheer number of different scenarios mean predictions are uncertain. Because very little warning can be given, people living in areas prone to tornadoes are advised to build a storm shelter in, under or near to their property, so that they can quickly take cover when a twister approaches.

DID YOU KNOW?

Since the 1980s, average tornado warning times have increased from 5 to 13 minutes

Building a storm shelter

A sturdy safe room is the key to surviving a fierce tornado



A heavy roof

A ceiling made from a 20-centimetre-thick slab of concrete will protect those inside from any falling debris.

A secure door

The five-centimetre-thick door must be attached to the shelter at five points and feature at least two dead bolt locks to hold it in place.

Ventilation

The ventilation pipe in the wall must bend downwards to allow air in but keep falling debris out.

Strong walls

The concrete walls must be at least 30 centimetres thick, reinforced with steel bars and feature no windows, which could shatter.

Thick foundations

The shelter must be secured to a 30-centimetre-thick and 45-centimetre-deep foundation so that it cannot be toppled or blown away.

Another slab of concrete

The foundation must be secured to an additional ten-centimetre-deep concrete slab to ensure it is anchored to the ground.

When strong winds get inside a building, they push the wall outwards, making it look as though it has exploded

TAKING SHELTER

IF A TORNADO STRIKES, SOME HIDING SPOTS ARE BETTER THAN OTHERS

Basement

The safest bet is to get low, avoid windows and surround yourself with as many walls as possible.

Car

Vehicles can get picked up by tornado winds, but the best option may be to keep driving in search of better shelter.

Office building

Many office blocks have large windows that can smash. Avoid lifts and get to the lowest level.

Under a bridge

The tunnel under a bridge or overpass can actually increase already violent tornado winds.

Caravan

Even if secured to the ground, caravans or mobile homes can easily get swept up in a tornado's path.

Ditch

Trying to get as low as possible is a good idea, but due to the risk of flash flooding, a ditch can be dangerous.

The United States has more tornadoes than any other country in the world, with an average of 1,000 each year

PREPARE FOR THE STORM

How can we prevent catastrophic damage?

Although methods for predicting extreme weather events are becoming more advanced, devastating storms can still take us by surprise. Therefore, it's a good idea to always be prepared, making sure your home is as storm-proof as possible, and putting an emergency plan in place for you and your family to follow.

Technology can also help to protect you and your home from the scary side of Mother Nature, with innovative products that can withstand the most extreme conditions. One of the weakest points of most houses during a hurricane are the windows, which can easily shatter to send shards of glass flying through the air and let wind, rain and debris inside. To prevent this, you can use a strengthened resin instead of glass, which will only crack on impact, and install hurricane shutters that can be quickly deployed and will block any holes that do appear.

However, if you're looking for an even sturdier place to take cover, then you could purchase a Concrete Canvas shelter, an inflatable structure made from fabric that hardens into concrete when doused with water. These emergency dwellings are water and fire proof, and can be deployed by two people in less than one hour.

Batten down the hatches

Discover how to keep you and your family safe before and after an extreme weather event

BEFORE STORM

AFTER STORM

Secure the windows
Board up any windows or doors that could break or shatter and let water and debris into the house.

Stock up
Keep a store of non-perishable food and drinking water in case you become trapped inside the house.

Reinforce the roof
Repair any loose roof tiles to reduce the risk of them being ripped off by strong winds.

Plan an escape
Keep the car's tank full of fuel so that if you have enough warning, you can evacuate to a nearby shelter.

Know first-aid
Keep a fully-stocked first-aid kit inside the house and read up on how to deal with common injuries.

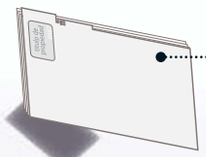
Prepare papers
Keep family documents and an itinerary of your household belongings in a waterproof container, and ensure everyone carries an ID card.

DID YOU KNOW?

In 2015, severe weather resulted in 155 deaths and cost $10 billion in the US alone

A violent storm can easily devastate a home if precautions are not taken

"Always be prepared by making sure your home is as storm-proof as possible"

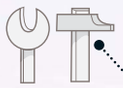


House documents
Ensure documents confirming your ownership of the property are kept safe to help with any insurance claims.

Safe to drink
Do not drink water from the mains water supply until you are sure it has not been contaminated.

Unplug
Disconnect any electrical devices and shut off the house circuit breaker in case there is a power surge.

Making calls
Only make emergency phone calls to avoid jamming the line for others who need to call for help.



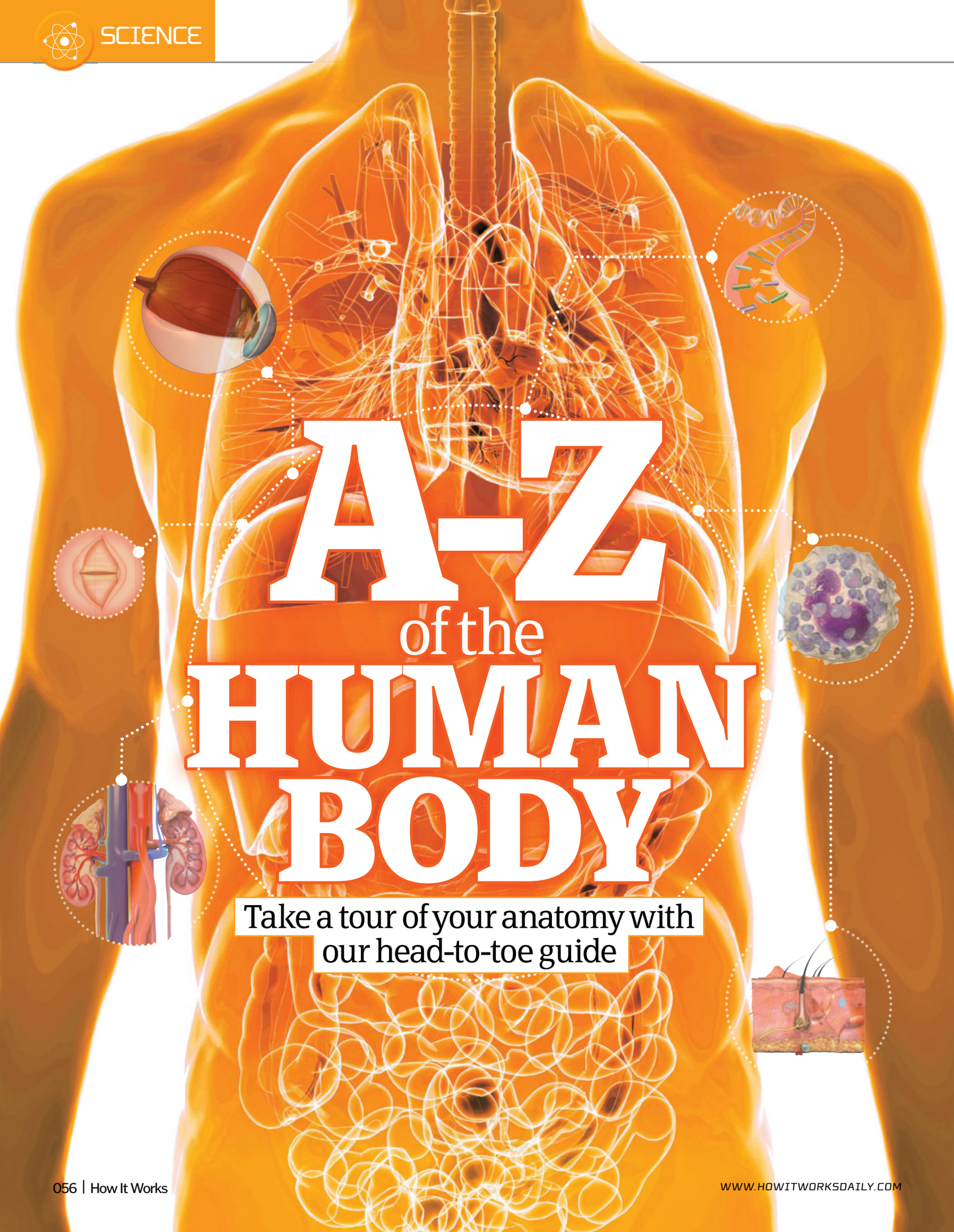
Gas leaks
Get a professional to check that there are no gas leaks or electrical faults before re-entering the property and using any appliances.

Switch off
Turn off the main gas valve in case there is a gas leak, and shut off the main water valve in case the supply becomes contaminated.

Don't touch
After the storm, stay away from any bare wires or damaged electrical equipment that could shock you.

Tune in
Use a battery-powered radio to get updates from local news reports, and to find out when it's safe to go outside.

Clear the area
Remove any dead trees or branches that could topple in high winds and cause damage or injury.



A-Z of the HUMAN BODY

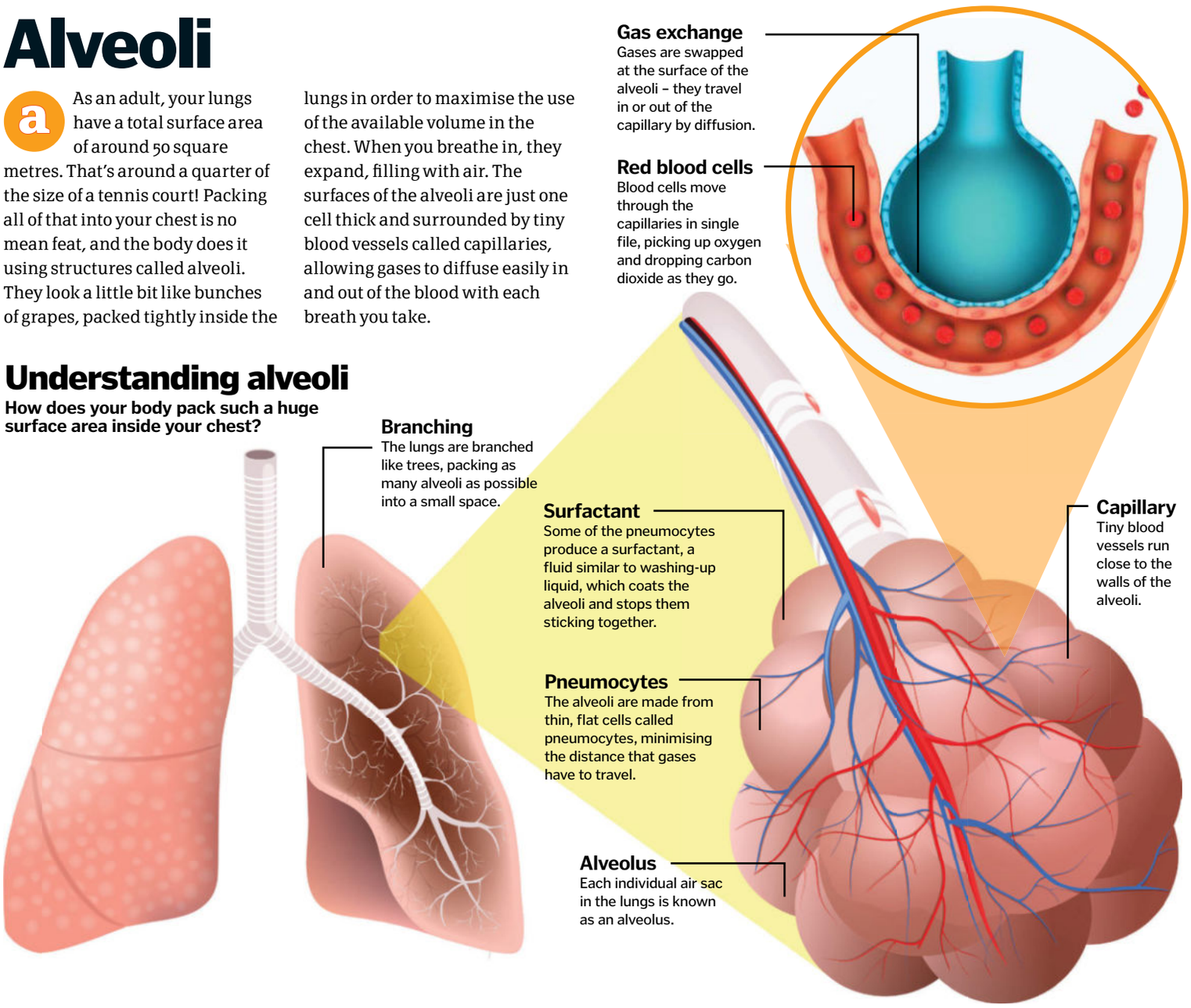
Take a tour of your anatomy with our head-to-toe guide

Alveoli

a As an adult, your lungs have a total surface area of around 50 square metres. That's around a quarter of the size of a tennis court! Packing all of that into your chest is no mean feat, and the body does it using structures called alveoli. They look a little bit like bunches of grapes, packed tightly inside the lungs in order to maximise the use of the available volume in the chest. When you breathe in, they expand, filling with air. The surfaces of the alveoli are just one cell thick and surrounded by tiny blood vessels called capillaries, allowing gases to diffuse easily in and out of the blood with each breath you take.

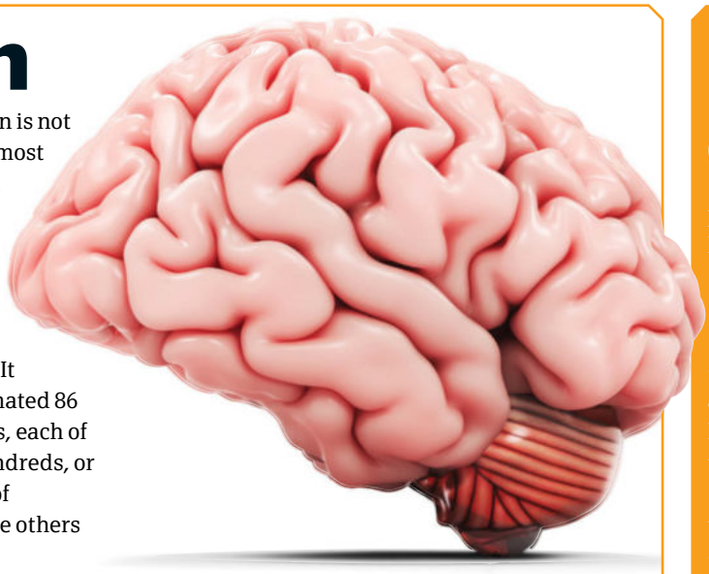
Understanding alveoli

How does your body pack such a huge surface area inside your chest?



Brain

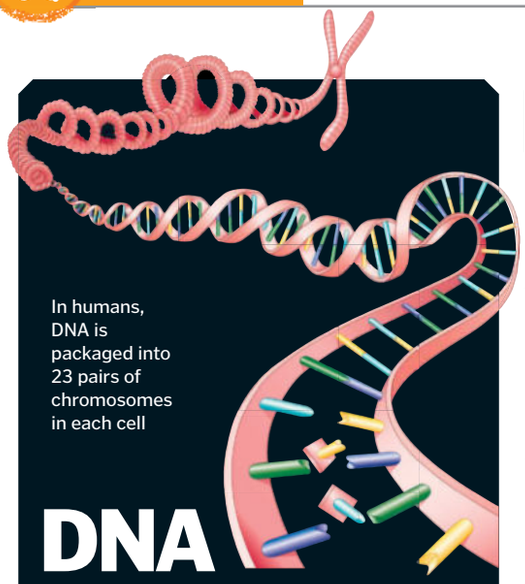
b The brain is not just the most complex structure in the human body, but it is also the most complex object in the known universe. It contains an estimated 86 billion nerve cells, each of which makes hundreds, or even thousands of connections to the others around it.



Cornea

c The cornea is the protective coating that keeps your eye free of dust and debris. It looks clear but is actually made up of several layers of cells. Light bends slightly as it passes through the cornea, helping to focus incoming rays on the back of your eye.

It is, in fact, possible to donate corneas for transplant, helping to restore vision to people with corneal damage.



In humans, DNA is packaged into 23 pairs of chromosomes in each cell

DNA

Perhaps the most important single structure inside your body is your DNA. Present in almost every cell (red blood cells get rid of theirs), it carries the genetic recipes needed to build, grow, repair and maintain you. These recipes are written in combinations of four-letter code (ACTG), and in humans are 3 billion letters long.

Fat

You have two main types of fat: brown and white. Brown fat burns calories to keep you warm, while white fat stores energy and produces hormones. Children have more brown fat than adults, and it's mainly found in the neck and shoulders, around the organs, and along the spinal cord.

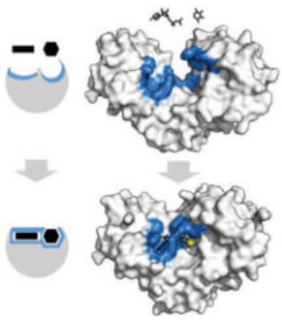
This scan shows the distribution of brown fat around the head, shoulders, heart and spine

Enzymes

Enzymes are often called 'biological catalysts', and their job is to speed up chemical reactions. You are full of dissolved chemicals with the potential to come together or break apart to form the biological building blocks that you need to stay alive, but the reactions happen too slowly on their own.

Enzymes are molecules with 'active sites' that lock on to other molecules, bringing them close together so that they can react, or bending their structures so that they can combine or break apart more easily. The enzymes themselves do not actually get involved in the reactions; they just help them to happen faster.

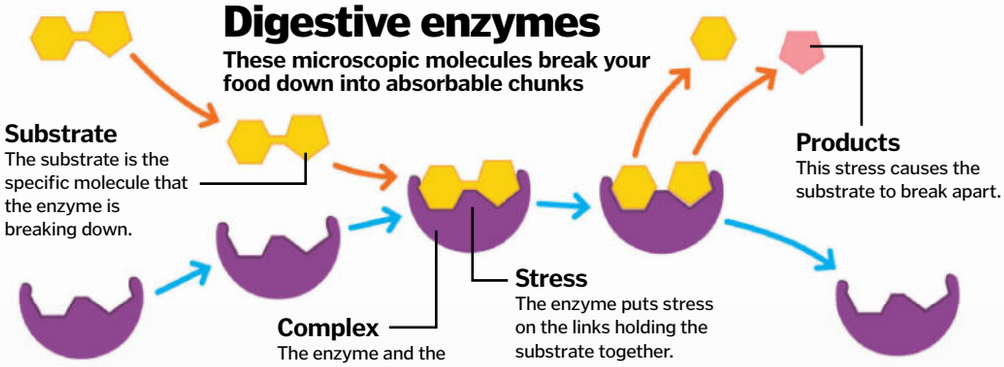
Some of the most well-known enzymes are the ones in your digestive system. These are important for breaking down the molecules in your food. However, these aren't the only enzymes in your body. There are others responsible for building molecules, snipping molecules, tidying up when molecules are no longer needed, and even destroying invading pathogens.



This enzyme brings two molecules close together so that they can react

Digestive enzymes

These microscopic molecules break your food down into absorbable chunks

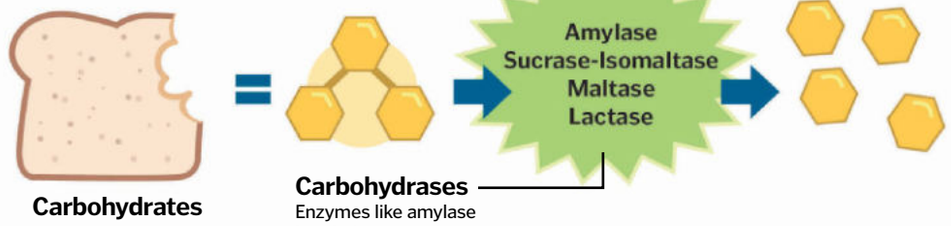


Substrate
The substrate is the specific molecule that the enzyme is breaking down.

Complex
The enzyme and the substrate join together to form a complex.

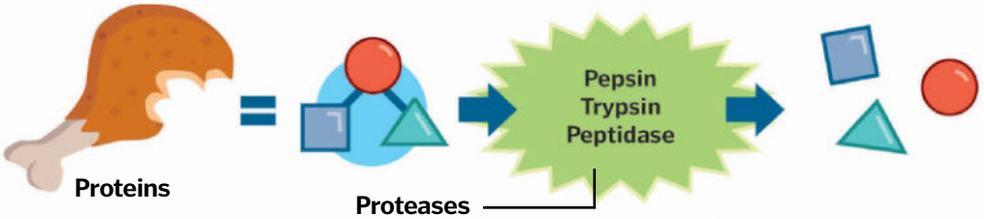
Stress
The enzyme puts stress on the links holding the substrate together.

Products
This stress causes the substrate to break apart.



Carbohydrates

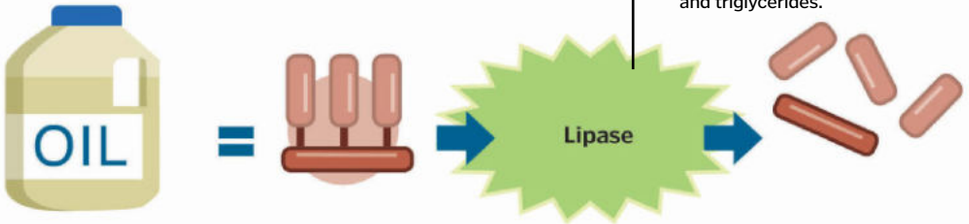
Carbohydrases
Enzymes like amylase break down carbohydrates into simple sugars.



Proteins

Proteases
Enzymes like pepsin break down proteins into amino acids.

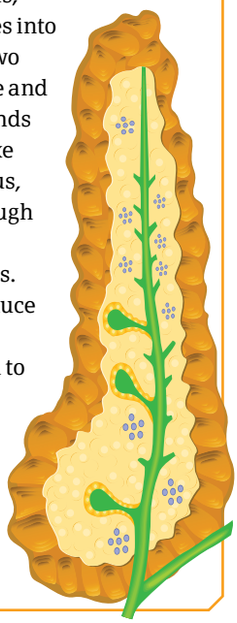
Fats



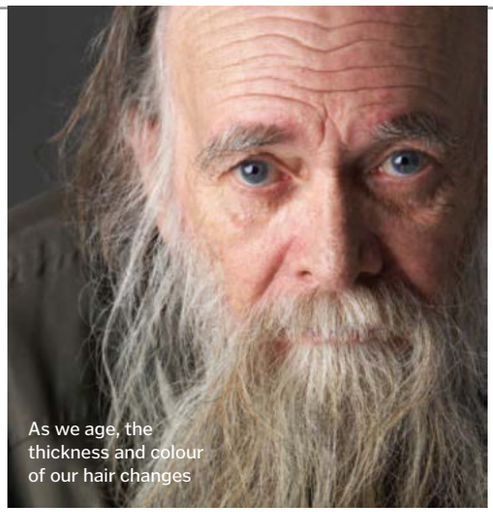
Lipases
Lipase breaks fats and oils into fatty acids and triglycerides.

Glands

These structures are responsible for producing and releasing fluids, enzymes and hormones into your body. There are two major types: endocrine and exocrine. Exocrine glands produce substances like sweat, saliva and mucus, and release these through ducts onto the skin or surfaces of other organs. Endocrine glands produce hormones, which are released into the blood to send chemical signals across the body.



The pancreas has both endocrine glands (blue clusters) and exocrine glands (green branches)



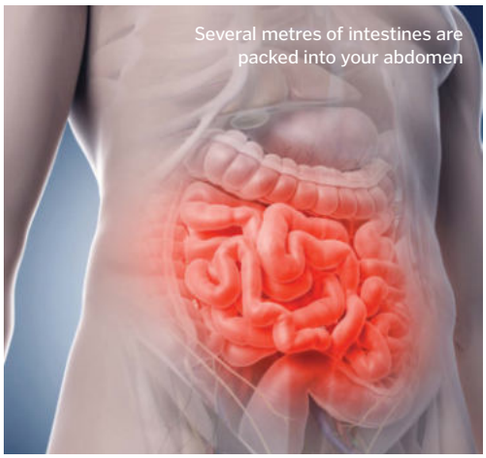
As we age, the thickness and colour of our hair changes

Hair

You have around 5 million hair follicles and, surprisingly, only around 100,000 of those are on your scalp. The others are spread across your body – on your skin, lining your eyelids, and inside your nose and ears. Hair has many functions, helping to keep you warm, trapping dirt and debris, and even (in the case of eyebrows) diverting sweat and rainwater away from your eyes.

Intestines

After exiting your stomach, food enters your intestines and begins a 7.5-metre journey out of your body. The small intestine comes first, and is filled with digestive enzymes that get to work breaking down and absorbing the molecules from your meal. After this, the large intestine absorbs as much water as possible before the waste is passed out.



Several metres of intestines are packed into your abdomen

Joints

There are more than 200 bones in the human body, and to make you move in all the right places, they are linked together by different types of joints.

In your hips and shoulders, you've got ball and socket joints, which allow the widest range of movement. They allow movement forwards, backwards, side-to-side and around in circles.

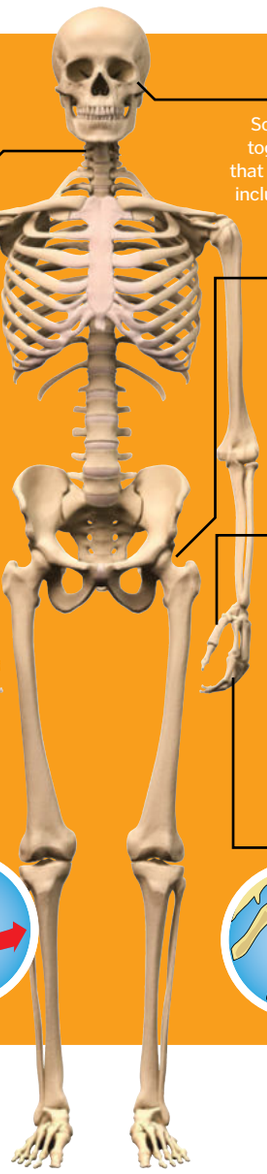
At the knees and elbows, you have hinge joints, which open and close just like a door. And in your wrists and ankles, there are gliding joints, which allow the bones to flex past one another. In your thumb, there is a saddle joint that enables a side-to-side and open-close motion.

Cartilage covers the ends of the bones at many joints, helping to prevent the surfaces from rubbing together, and cushioning the impact as you move. Many joints are also contained within a fluid-filled capsule, which provides lubrication to keep things moving smoothly. These are called synovial joints.

"There are more than 200 bones in the human body"

Types of joints

Each type of joint in your body allows for a different range of movement



Immovable
Some bones are fused together to form joints that don't actually move, including the bones that make up the skull.

Ball and socket
These joints allow the widest range of movement. The end of one bone is shaped like a ball, and rotates inside another cup-shaped bone.

Saddle
The only saddle joints in the human body are in the thumbs. They allow forwards, backwards and sideways motion, but only limited rotation.

Ellipsoidal
These joints, such as at the base of your index finger, allow forward and backwards movement, and some side-to-side, but they don't rotate.

Pivot
These joints are adapted for turning, but they do not allow much side-to-side or forwards and backwards movement.

Hinge
The knees and elbows can move forwards and backwards, but not side to side.

Gliding
Gliding joints are found between flat bones, enabling them to slide past one another.

Kidneys

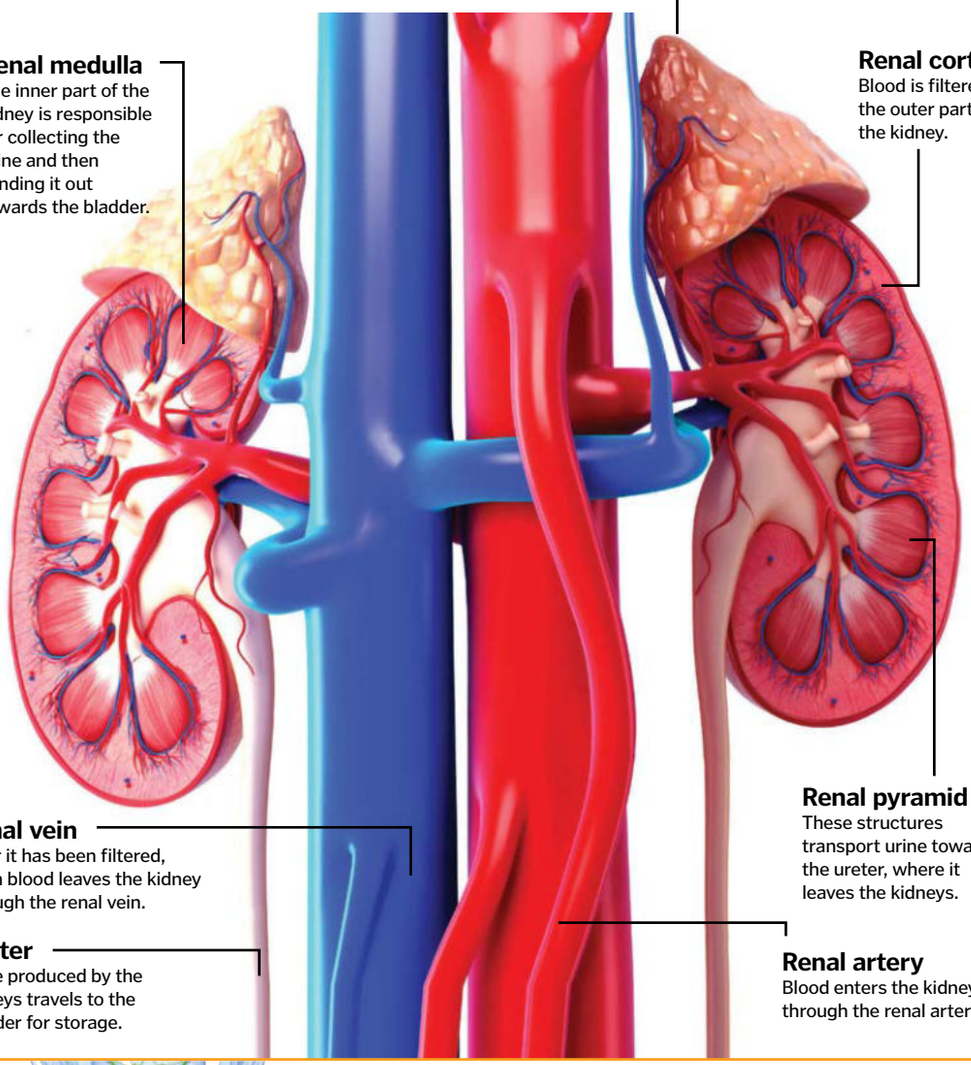
Your kidneys keep your blood clean and your body properly hydrated. Blood passes in through knots of blood vessels that are wider on the way in and narrower on the way out. This creates an area of high pressure that forces water and waste out through gaps in the vessel walls. Blood cells and proteins remain in the bloodstream. Each kidney has around a million of these miniature filtering systems, called nephrons, cleaning the blood every time it passes through.

The fluid then tracks through bendy tubes (known as convoluted tubules), where important minerals are collected and returned to the blood. Excess water and waste products are sent on to the bladder as urine to be excreted. Depending on how much salt and water are in your body, your kidneys adjust the amount of fluid that they get rid of, helping to keep your hydration levels stable.

"Your kidneys keep your blood clean and your body hydrated"

The kidneys

These simple-looking organs are packed with microscopic filtration machinery



Adrenal gland
On top of each kidney is an endocrine gland that produces hormones, including adrenaline.

Renal medulla
The inner part of the kidney is responsible for collecting the urine and then sending it out towards the bladder.

Renal cortex
Blood is filtered in the outer part of the kidney.

Renal pyramid
These structures transport urine towards the ureter, where it leaves the kidneys.

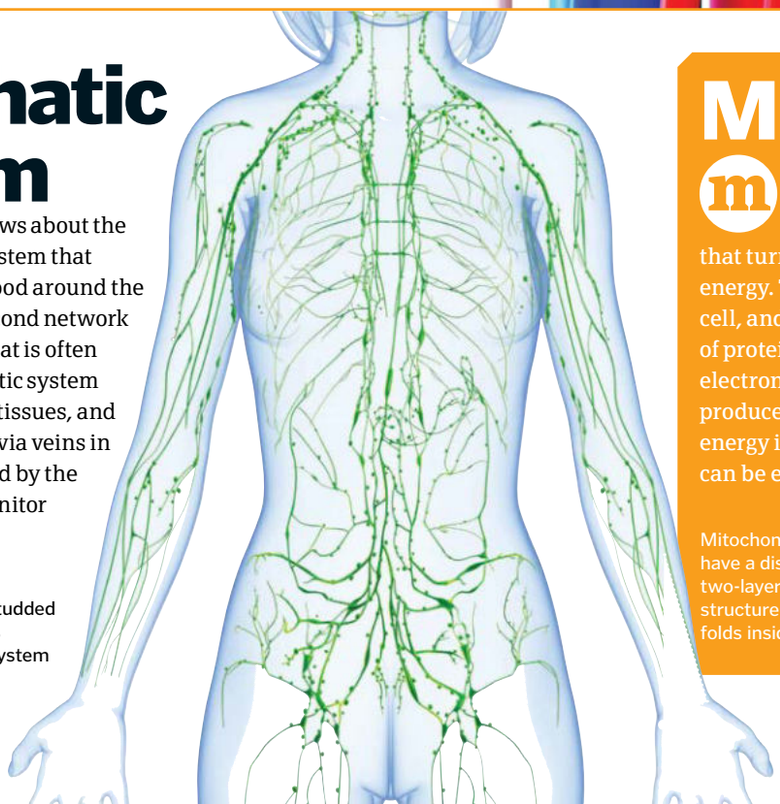
Renal vein
After it has been filtered, clean blood leaves the kidney through the renal vein.

Ureter
Urine produced by the kidneys travels to the bladder for storage.

Renal artery
Blood enters the kidney through the renal artery.

Lymphatic system

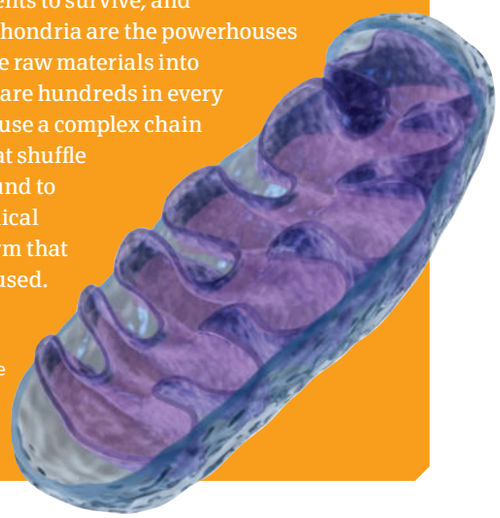
Everyone knows about the circulatory system that transports blood around the body, but there is a second network of tubes and vessels that is often forgotten. The lymphatic system collects fluid from the tissues, and returns it to the blood via veins in the chest. It is also used by the immune system to monitor and fight infection.



The lymphatic system is studded with lymph nodes, used as outposts by the immune system

Mitochondria

We know that our bodies need oxygen and nutrients to survive, and mitochondria are the powerhouses that turn these raw materials into energy. There are hundreds in every cell, and they use a complex chain of proteins that shuffle electrons around to produce chemical energy in a form that can be easily used.



Mitochondria have a distinctive two-layered structure, with folds inside

Nervous system

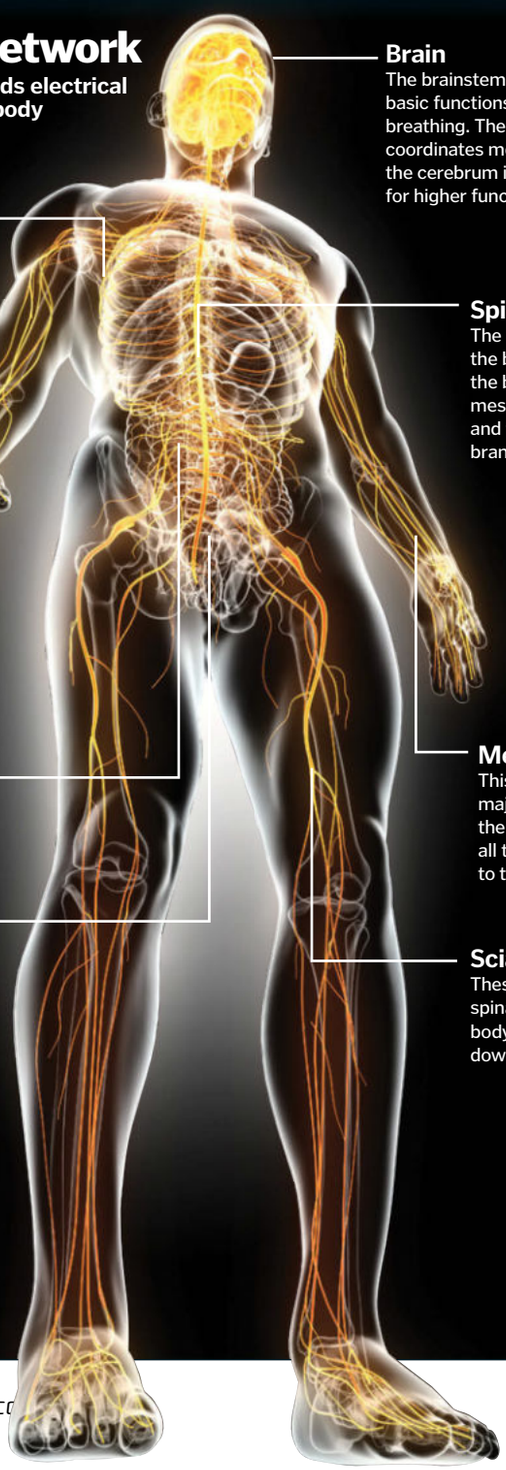
This is your body's electrical wiring, transmitting signals from your head to your toes and everywhere in between. The nervous system can be split into two main parts: central and peripheral.

The central nervous system is the brain and spinal cord, and makes up the control centre of your body. While the brain is in charge of the vast majority of signals, the spinal cord can take care of some things on its own. These are known as 'spinal reflexes', and include responses like the knee-jerk reaction. They bypass the brain, which allows them to happen at super speed.

The peripheral nervous system is the network of nerves that feed the rest of your body, and it can be further divided into two parts: somatic and autonomic. The somatic nervous system looks after everything that you consciously feel and move, like clenching your leg muscles and sensing pain if you step on a nail. The autonomic system takes care of the things that go on in the background, like keeping your heart beating and your stomach churning.

Your nerve network

The nervous system sends electrical messages all over your body



Brain
The brainstem controls basic functions like breathing. The cerebellum coordinates movement, and the cerebrum is responsible for higher functions.

Thoracic nerves
There are 12 pairs of thoracic nerves, 11 of which lie between the ribs. They carry signals to the chest and abdomen.

Spinal cord
The spinal cord links the brain to the rest of the body, feeding messages backwards and forwards via branching nerves.

Ulnar nerve
These nerves run over the outside of the elbow, and are responsible for that odd 'funny bone' feeling.

Median nerve
This is one of the major nerves of the arm, and runs all the way down to the hand.

Lumbar nerves
There are five pairs of lumbar nerves, supplying the leg muscles.

Sacral nerves
There are five pairs of sacral nerves, supplying the ankles, as well as looking after bladder and bowel function.

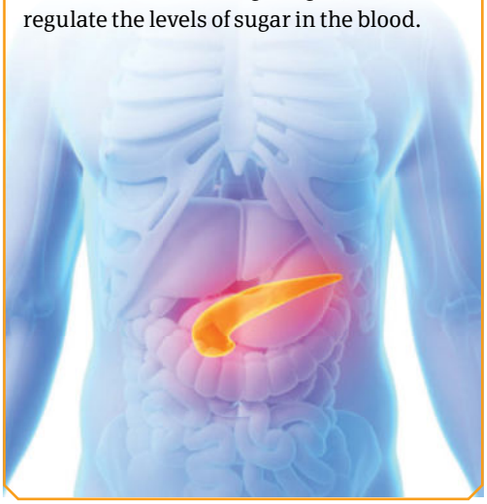
Sciatic nerves
These are the longest spinal nerves in the body, with one running down each leg.

Oesophagus

Sometimes known as the 'food pipe', this stretchy muscular tube links your mouth to your stomach. When you swallow, circular muscles contract to push food into your digestive tract, starting at the top and moving down in waves.

Pancreas

This leaf-shaped organ plays two vital roles in digestion. It produces enzymes that break down food in the small intestine, and it makes the hormones insulin and glucagon, which regulate the levels of sugar in the blood.



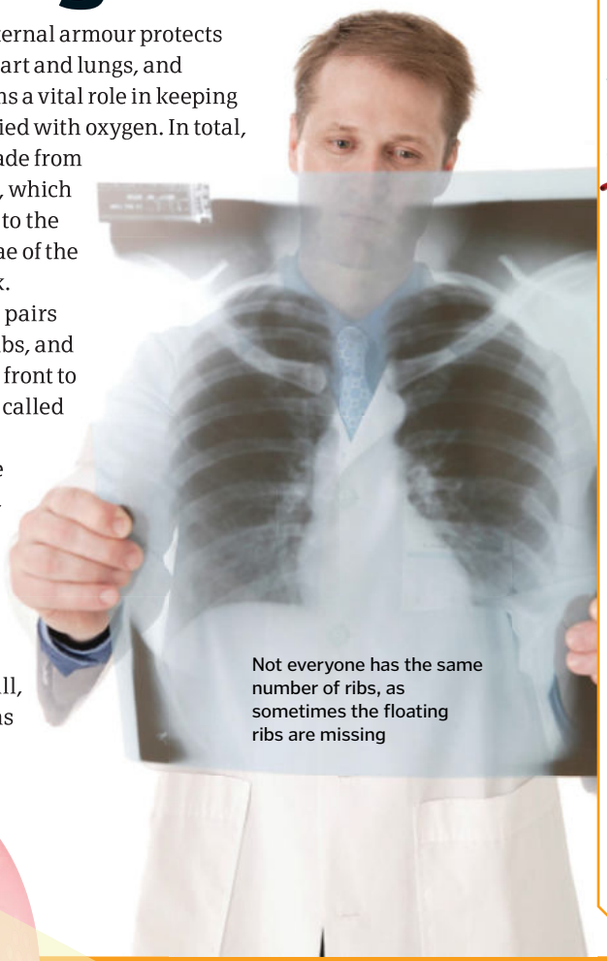
Quadriceps

There aren't many body parts that begin with the letter Q, but this bundle of four muscles in the upper leg is an important one. The quadriceps femoris connect the pelvis and thigh to the knee and shinbone, and are used to straighten the leg.

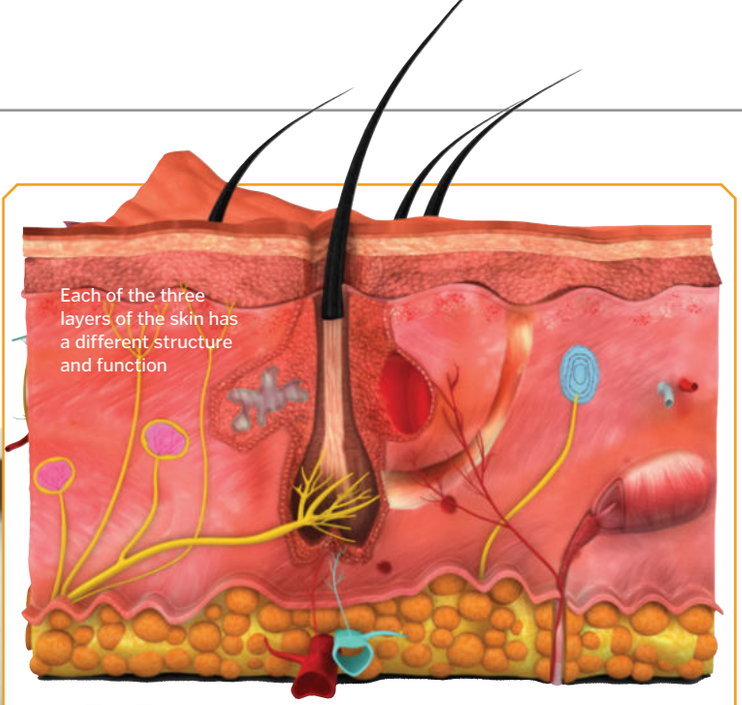
Ribcage

This internal armour protects your heart and lungs, and performs a vital role in keeping your body supplied with oxygen. In total, the ribcage is made from 24 curved bones, which connect in pairs to the thoracic vertebrae of the spine at the back.

Seven of these pairs are called true ribs, and are linked at the front to a wide, flat bone called the sternum (or breastbone). The next three pairs, known as false ribs, connect to the sternum indirectly, and the final two don't link up at all, and are known as floating ribs.



Not everyone has the same number of ribs, as sometimes the floating ribs are missing



Each of the three layers of the skin has a different structure and function

Skin

Your skin is the largest organ in your body. It is made up of three distinct layers: the epidermis on the outside, the dermis beneath, and the hypodermis right at the bottom.

The epidermis is waterproof, and is made up of overlapping layers of flattened cells. These are constantly being replaced by a layer of stem cells that sit just beneath. The epidermis also contains melanocytes, which produce the colour pigment melanin.

The dermis contains hair follicles, glands, nerves and blood vessels. It nourishes the top layer of skin, and produces sweat and sebum. Under this is a layer of supporting tissue called the hypodermis, which contains storage space for fat.

Tongue

The tongue is a powerful muscle with several important functions. It is vital for chewing, swallowing, speech and even keeping your mouth clean, but its most well-known job is to taste.

The bumps on the tongue are not all taste buds; they are known as papillae, and there are four different types. At the very back of the tongue are the vallate papillae, each containing around 250 taste buds. At the sides are the foliate papillae, with around 1,000 taste buds each. And at the tip are the fungiform (mushroom-shaped) papillae, with a whopping 1,600 taste buds each.

The rest of the bumps, covering most of the tongue, are known as filiform papillae, and do not have any taste buds at all.

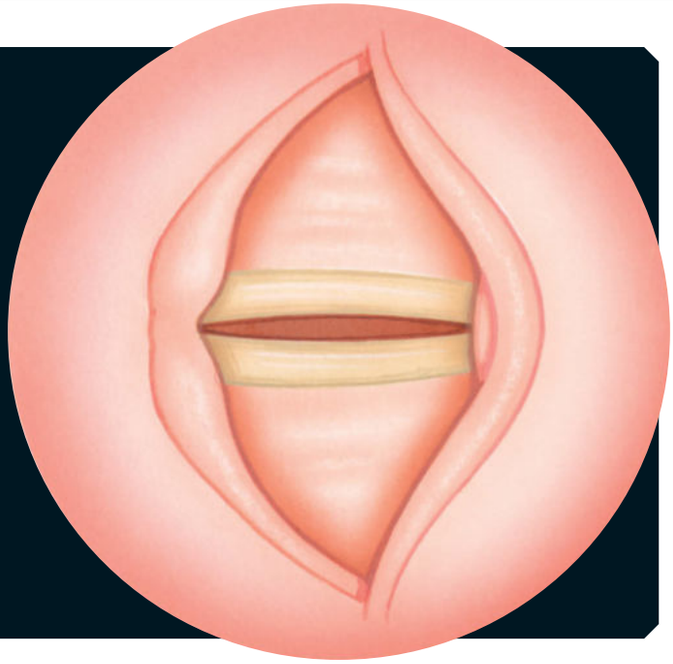
Umbilical cord

This spongy structure is packed with blood vessels, and connects a developing baby to its placenta. The placenta attaches to the wall of the mother's uterus, tapping into her blood supply to extract oxygen and nutrients. After birth, the cord dries up and falls away, leaving a scar called the belly button.

The umbilical cord is usually cut at birth, separating the baby from the placenta

Vocal cords

V The vocal cords are folds of membrane found in the larynx, or voice box. They can be used to change the flow of air out of the lungs, allowing us to speak and sing. As air passes through the gap between the folds, they vibrate, producing sound.



When the vocal cords are closed, pressure builds and they vibrate

Xiphoid process

X This is the technical term used for the little lump that can be found at the bottom of your sternum, or breastbone. Medical professionals use the xiphoid process as a landmark in order to find the right place for chest compressions during CPR.

White blood cells

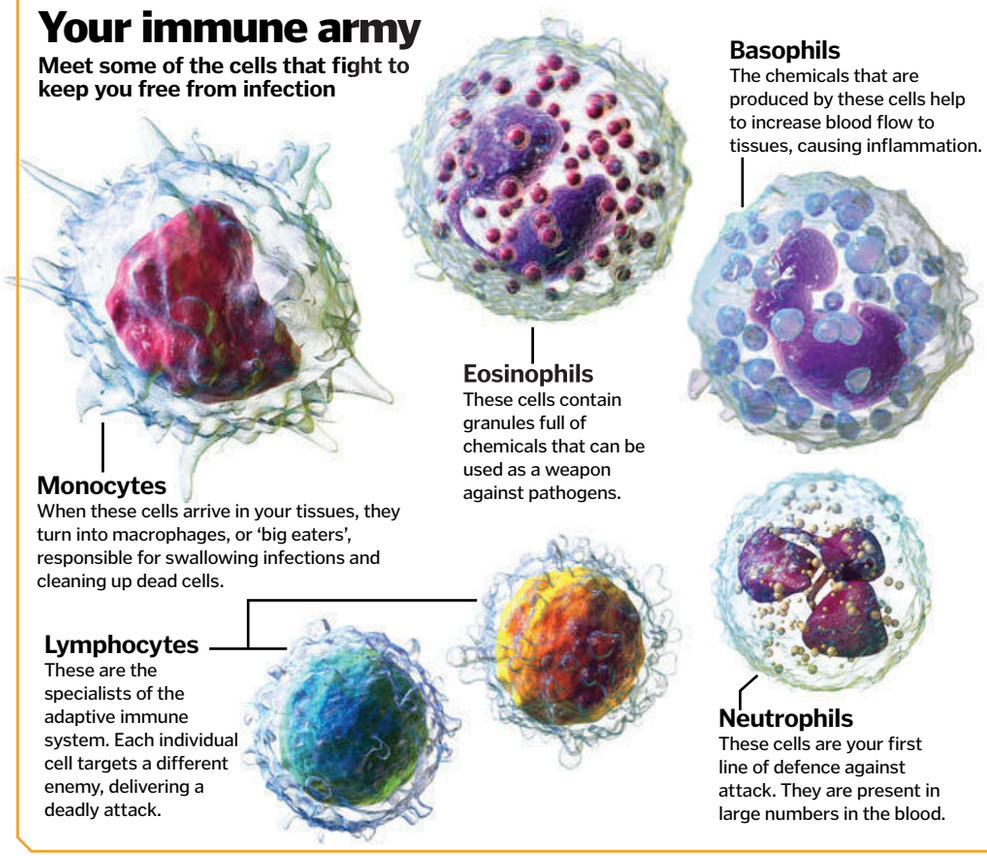
W These specialist cells make up your own personal army, tasked with defending your body from attack and disease. There are several different types, each with a unique role to play in keeping your body free of infection.

The first line of defence is called the innate immune system. These cells are the first ones on the scene, and they work to contain infections by swallowing and digesting bacteria, as well as killing cells that have been infected with viruses.

If the innate immune system can't keep the infection at bay, then they call in the second layer of defence – the adaptive immune system. These cells mount a stronger and more specific attack, and can even remember which pathogens they've fought before.

Your immune army

Meet some of the cells that fight to keep you free from infection



Monocytes
When these cells arrive in your tissues, they turn into macrophages, or 'big eaters', responsible for swallowing infections and cleaning up dead cells.

Eosinophils
These cells contain granules full of chemicals that can be used as a weapon against pathogens.

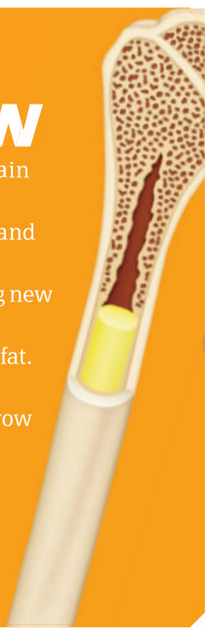
Basophils
The chemicals that are produced by these cells help to increase blood flow to tissues, causing inflammation.

Lymphocytes
These are the specialists of the adaptive immune system. Each individual cell targets a different enemy, delivering a deadly attack.

Neutrophils
These cells are your first line of defence against attack. They are present in large numbers in the blood.

Yellow marrow

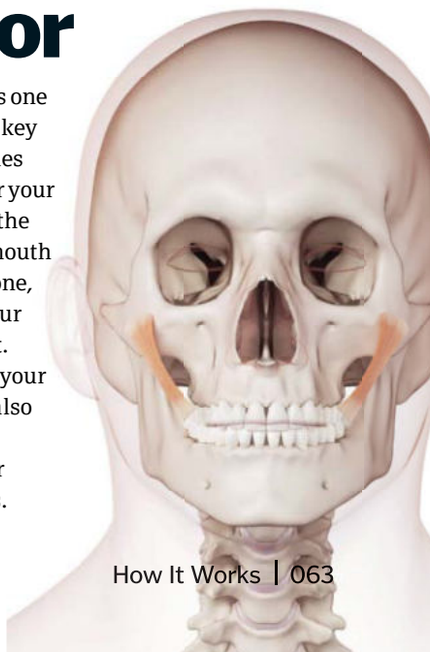
Y There are two main types of bone marrow: yellow and red. Red marrow is responsible for producing new blood cells, while yellow marrow contains mainly fat. Red marrow gradually changes into yellow marrow as you get older.



Yellow marrow is mainly found in the long bones of the arms and legs

Zygomaticus major

Z This is one of the key muscles responsible for your smile, joining the corner of the mouth to the cheekbone, and pulling your lips up and out. Depending on your anatomy, it is also the muscle responsible for cheek dimples.



The eye irritation associated with chlorine is actually caused by the chemical reacting with human sweat

How does chlorine clean swimming pools?

The chemical reaction that stops swimmers from getting sick

With hundreds of people taking a dip each day, public swimming pools are a prime place for water-borne diseases, such as E. coli, to spread. Thankfully, a clever chemical can be used to keep your splashing sanitary.

When chlorine is added to pool water, it dissolves to form hypochlorous acid, a weak acid that acts as a disinfectant. It kills bacteria through a process called oxidation, which destroys protein structures inside the bacterial cells, causing them to die. As the water becomes more acidic, the hypochlorous acid itself splits up to form hypochlorite ions, which are less efficient at cleaning water. Therefore, for more effective disinfection, as well as comfortable swimming, the acidity of the pool water must be continuously monitored and kept at a neutral pH between 7.2 and 7.8.

Although it is effective at cleaning pools, chlorinated water also has some irritating side effects for swimmers. However, it's not the chlorine itself that's directly responsible for the red eyes we sometimes experience after a visit to the pool. This is the result of ammonia compounds, found in human sweat and urine, reacting with the hypochlorous acid to form chloromines, a compound that's also responsible for that strong chemical smell in swimming pools.

60 SECOND SCIENCE

Hydraulics

THE SCIENCE BEHIND USING LIQUID POWER TO DO HEAVY LIFTING

BACKGROUND

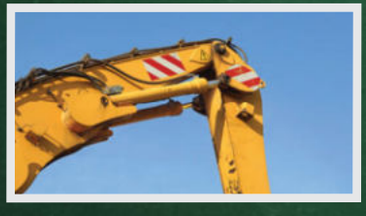
Hydraulics is the system of using liquids to produce power. Liquids can't easily be compressed, so pushing on them transmits pressure through them. The pressure is evenly transferred through the liquid, so a small push can be used to create a large force elsewhere. This can be used to move pistons, which in turn can be used to perform work, such as lifting with a crane or braking a car.

IN BRIEF

Gases can be squashed, pushing the molecules closer together to fit into a smaller space, but liquids are hard to compress, as the molecules are close already. Particles bump around as they move, generating pressure. Push on a liquid, and pressure is increased.

In a container with two cylinders and two pistons, connected by a fluid, when you push down on a piston in the first cylinder, it will push a piston up in the second. The pressure is equal to the force applied, divided by the cross-sectional area of the piston.

Put a bigger piston at the other end of the container, and the pressure can be used to generate a larger force. You can see why if you rearrange the equation - force is equal to pressure multiplied by cross-sectional area. If the area of the second piston goes up, so does the force generated.



Hydraulics are used to perform heavy industrial work

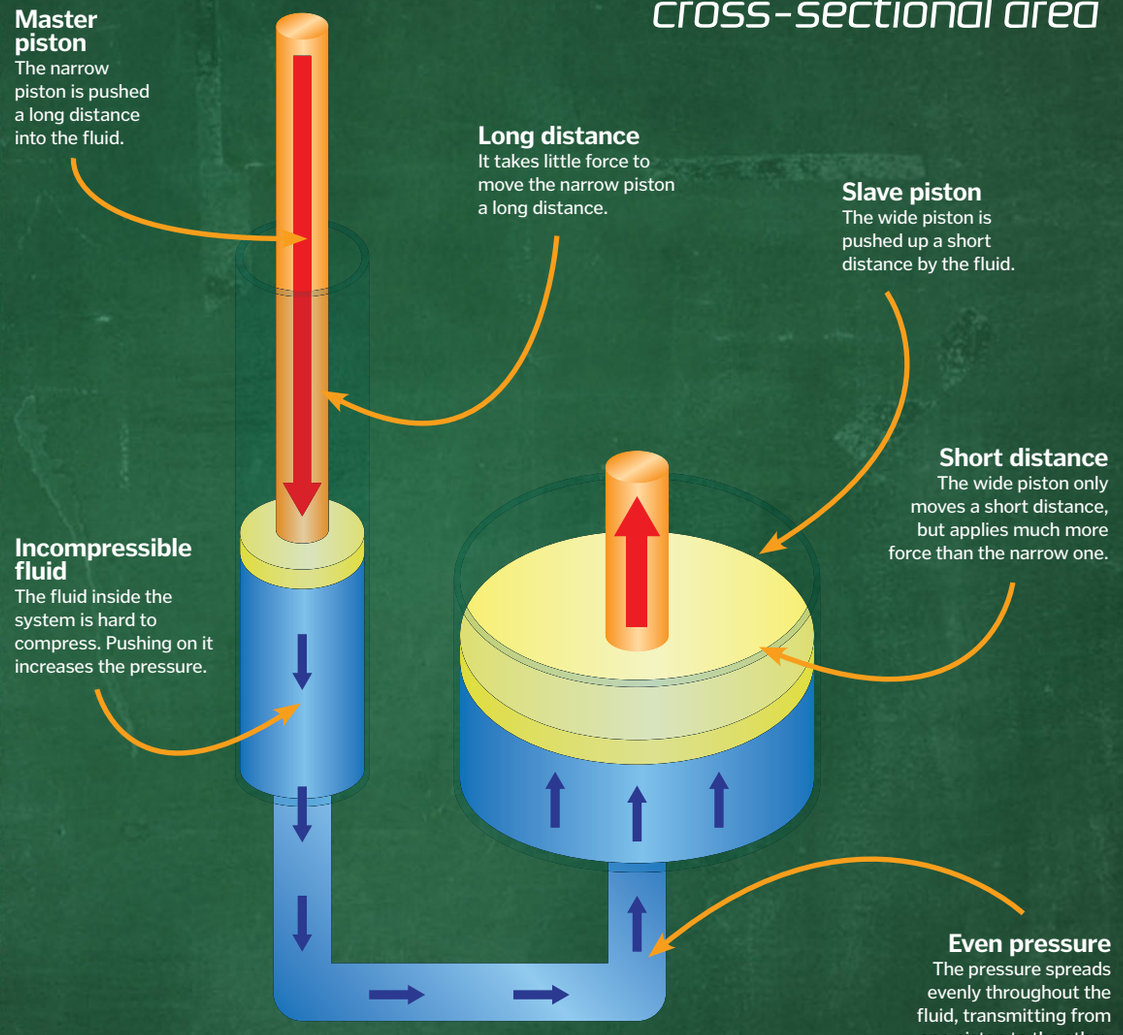
SUMMARY

Using a small piston to compress a fluid requires little force, but generates a lot of pressure. This pressure can be used to move a larger piston with greater force.

Inside hydraulics

How do hydraulic systems generate so much force?

Force = pressure x cross-sectional area



PASCAL'S PRINCIPLE

BLAISE PASCAL WAS A FRENCH MATHEMATICIAN IN THE 17TH CENTURY, AND RESPONSIBLE FOR OUR UNDERSTANDING OF PRESSURE AND HYDRAULICS. HE EXPLAINED THAT WHEN YOU PUSH ON FLUID IN A CLOSED CONTAINER, THE PRESSURE IS TRANSMITTED EQUALLY IN ALL DIRECTIONS. A PRESSURE CHANGE AT ONE SIDE OF THE CONTAINER IS TRANSMITTED TO ALL OTHER PARTS OF THE CONTAINER, AND TO THE WALLS. THIS IS KNOWN AS PASCAL'S PRINCIPLE.

HIS WORK ALSO INCLUDED UNDERSTANDING ATMOSPHERIC PRESSURE. SO IMPORTANT WERE HIS DISCOVERIES THAT THE STANDARD UNIT FOR PRESSURE WAS NAMED THE PASCAL (PA).

PASCAL WAS A POLYMATH, AND ALSO WORKED ON THE FOUNDING PRINCIPLES OF PROBABILITY WITH PIERRE DE FERMAT.

Welcome to Venus

The hellish world often described as Earth's evil twin

Imagine, in a couple of billion years, Earth's atmosphere becomes so thick that the planet increasingly heats up. Our oceans begin to boil, life struggles to survive, and the ground turns into a deathly, poisonous desert.

It sounds extreme but, that's pretty much what we think happened to Venus, the second closest planet to the Sun after Mercury. When the planets formed approximately 4.6 billion years ago, Venus and Earth were somewhat similar – and they still are to this day. They are both rocky planets, roughly equivalent in size and mass, and have a similar chemical composition.

And, at one point in its history, we think Venus had oceans just like Earth. But unlike our planet, these oceans did not stick around long enough for life to arise, or so we think. Instead, a combination of an increasingly luminous Sun and harsh solar wind meant that Venus went through an astonishing transformation – and it's one that might befall us far in the future.

The result of these changes meant that the water on Venus evaporated into the atmosphere. This thickened the atmosphere, making Venus hotter and hotter, until the carbon itself from the rocks evaporated (or sublimated) into the atmosphere, mixing with oxygen to form carbon dioxide. The atmosphere got thicker, and the planet got hotter and hotter, until it turned into the world we see today. We call this a runaway greenhouse effect.

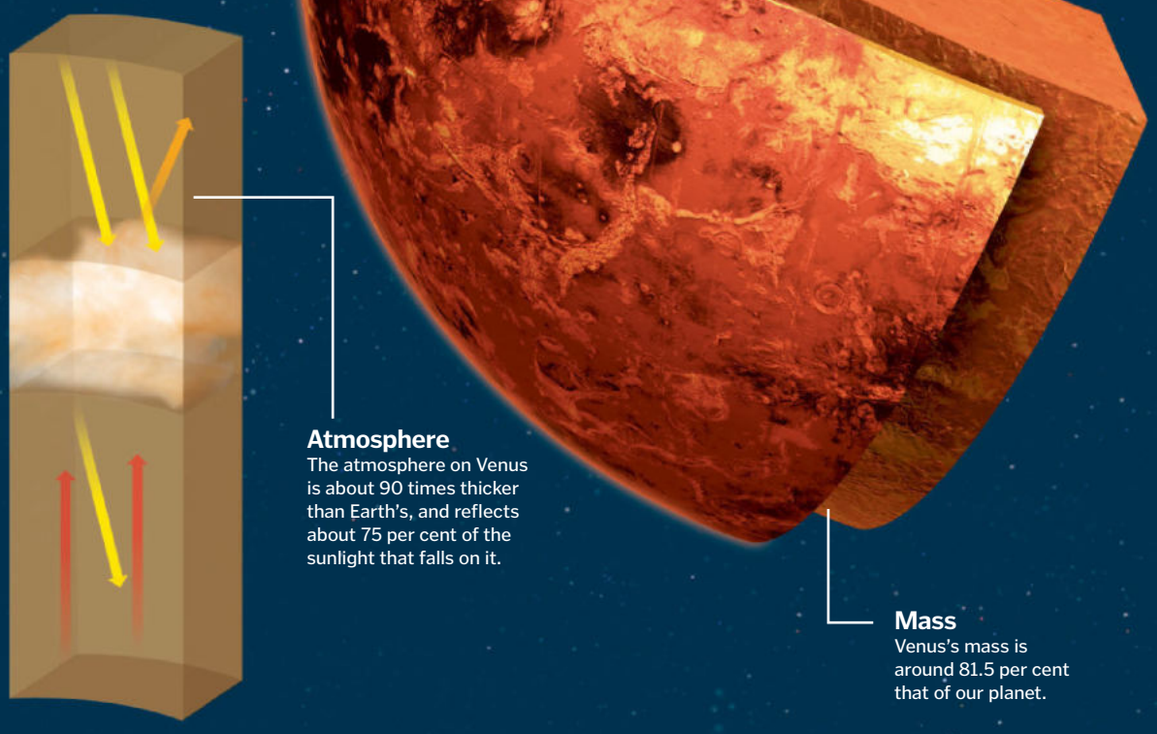
And what is that world we see today? Well, it's a fascinating one in its own right. Venus retains that thick atmosphere, meaning its surface is obscured from our view. But thanks to a series of Russian landers in the 1960s, 70s and 80s, and subsequent NASA and ESA orbiters, we have some idea of what's going on there.

The surface temperature on Venus is hot enough to melt lead, at more than 450 degrees Celsius on average, making it the hottest planet in the Solar System. Its surface is covered in volcanic features, and we think it may still have active volcanoes today. Winds tear around the planet at hundreds of kilometres per hour and sulphuric acid falls as rain in the atmosphere. These hellish conditions explain why Venus is known as 'Earth's evil twin'. If we're not careful with our own planet, though, Venus might be a glimpse of what is to come.

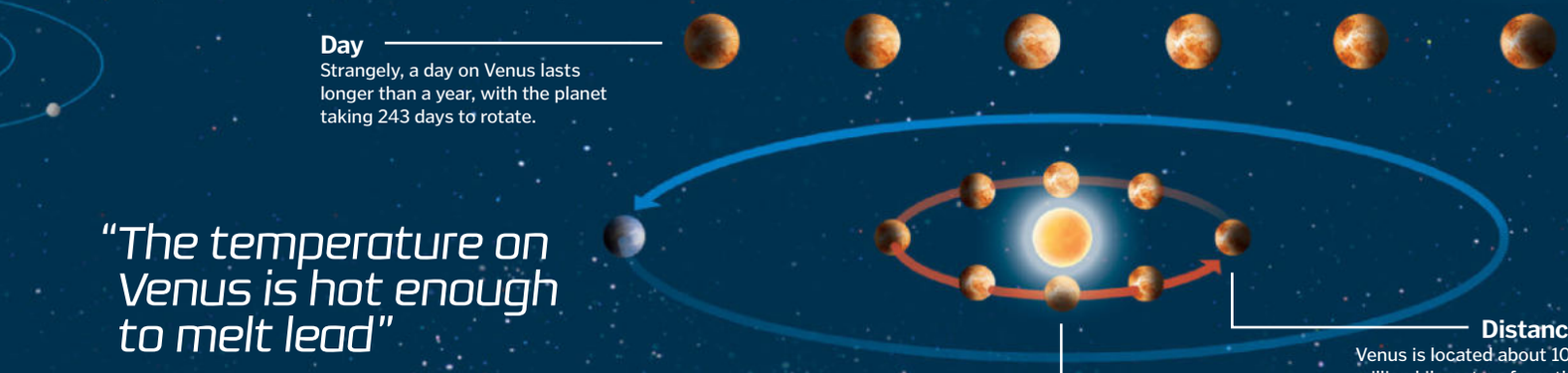
Inside Venus

What we know about the hottest planet in the Solar System

The Soviet Union's Venera probes returned our only images from the surface of Venus



Day
Strangely, a day on Venus lasts longer than a year, with the planet taking 243 days to rotate.



"The temperature on Venus is hot enough to melt lead"

Distance
Venus is located about 108 million kilometres from the Sun, about 72 per cent of Earth's distance.

Year
It takes Venus 224.7 Earth days to complete an orbit around the Sun.

Core
We think Venus has a core made of liquid iron and nickel, about 6,000 kilometres in diameter.

Surface
Compared to worlds like Mars and Mercury, Venus' surface is quite smooth, probably due to volcanoes erasing its history.

Size
Venus is slightly smaller than Earth, at about 95 per cent of our planet's diameter.

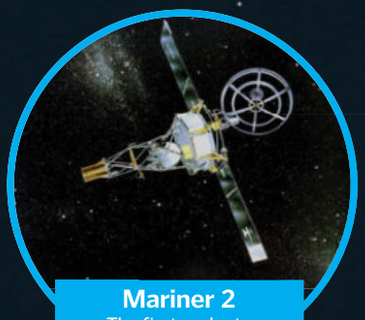
Crust
The crust of Venus is much more rigid than Earth's. It is 50 kilometres thick, and made mostly of silicate rocks.

Magnetic field
Venus has a very weak magnetic field, possibly because its core is not rotating fast enough, unlike Earth's.

Volcanoes may still be erupting on Venus' surface

Exploring Venus

A history of missions that we have sent to this world

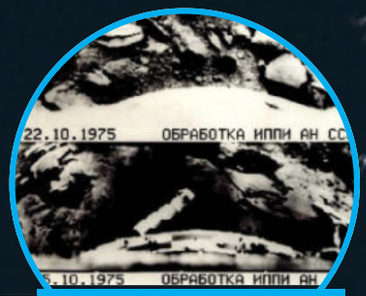


Mariner 2

The first probe to successfully fly past Venus was America's Mariner 2 on 14 December 1962, following a failed attempt by the Soviet Union the previous year.

Venera 7

Several Soviet landers attempted to touch down on Venus in the 1960s, but the first to successfully land was Venera 7 on 15 December 1970.

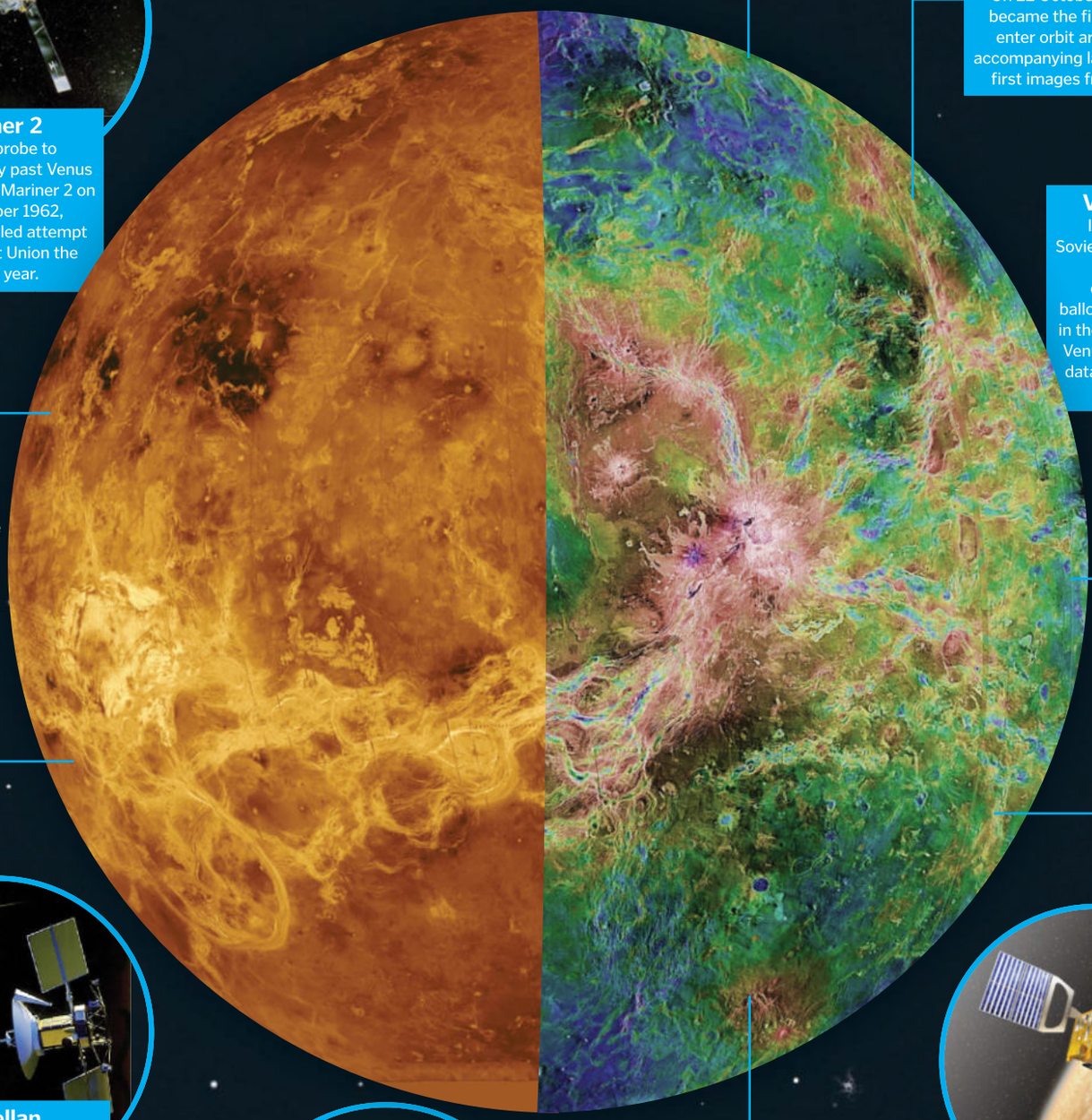


Venera 9

On 22 October 1975, Venera 9 became the first spacecraft to enter orbit around Venus. Its accompanying lander returned the first images from the surface.

Vega 1 and 2

In June 1985, the Soviet Union's Vega 1 and 2 probes deployed helium balloons that floated in the atmosphere of Venus, and returned data for around two Earth days.



Both images of Venus shown here were captured by the Magellan probe. The left hemisphere shows the planet in radar and the right is colour coded to highlight elevation

Magellan

The US Magellan probe entered orbit around Venus on 10 August 1990, mapping more than 98 per cent of the surface. Both views of Venus here were made with data from Magellan.

Akatsuki

Our most recent mission to Venus is Japan's Akatsuki, which failed to enter orbit in December 2010 but swung around the Solar System for a second successful attempt five years later.

Venus Express

The European Space Agency's Venus Express probe entered orbit around the planet on 11 April 2006, ending with a dive into the Venusian atmosphere in January 2015.

Could we actually live on Venus?

The short and boring answer is no. At least, not yet. On the surface, the temperature is hot enough to melt lead, and the pressure is 90 times as strong as that on Earth. You would be crushed to a sizzling pulp in seconds.

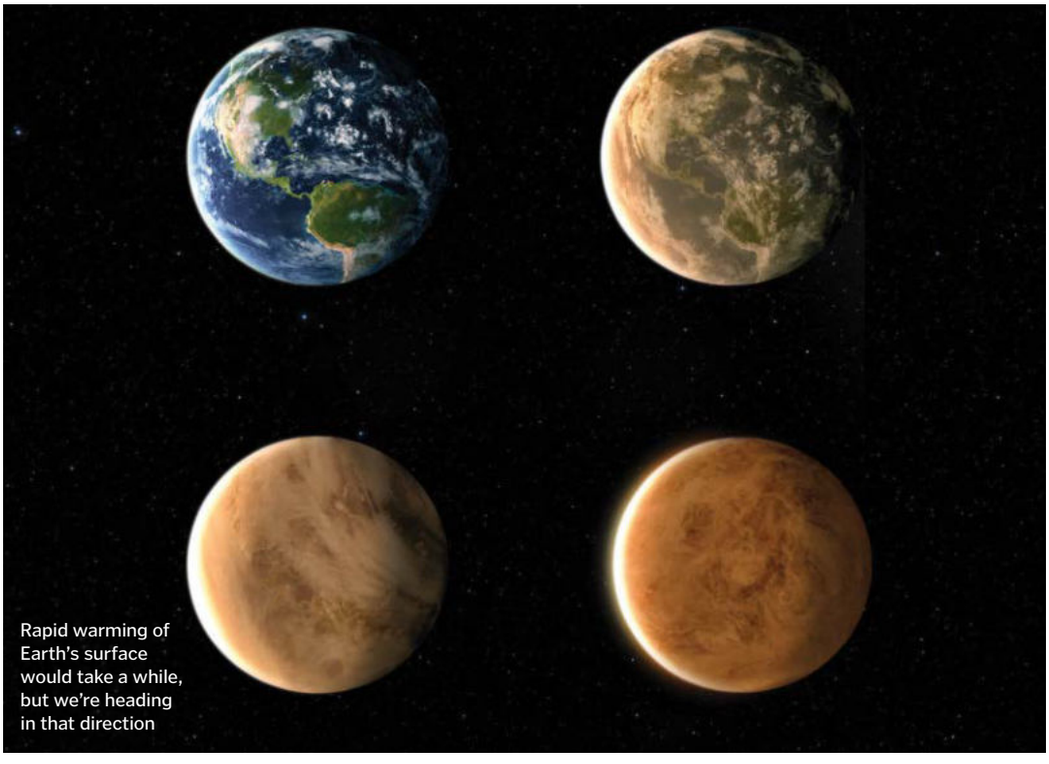
However, supposing that in the future we can overcome these problems, then what could we expect? Well, the surface is completely dry, although we think there may still be active volcanoes in places. The gravity, at 91 per cent, is also comparable to that on Earth. The air is so thick, though, that moving around would feel like pushing through water.

And the surface would be a strange place. Aside from the alien environment, the Sun would rise in the west and set in the east due to Venus' backwards rotation. And the sky would be an orange-red, rather than blue like on Earth.

But while we can't live on Venus, we could live above it. About 50 kilometres above the surface, the pressure and temperature is similar to that on Earth. All we'd need would be breathing suits to survive the sulphuric acid. Theoretically, humans could live on floating cities here. We just don't quite have the technology – or desire – to do this yet.

"The air is so thick that moving around would feel like pushing through water"

Floating cities in the sky have been touted as one way to colonise Venus



Rapid warming of Earth's surface would take a while, but we're heading in that direction

Earth's future

On Earth, global warming is causing our climate to warm at a rather alarming rate. And if you want a good indicator of just how bad things can get, look no further than Venus.

Rapid warming of the Venusian surface in the past released large amounts of water vapour and carbon dioxide into its atmosphere, which raised the surface to its scorching temperature today, known as a runaway greenhouse effect. If the same thing were to happen on Earth, all life would die.

While this isn't going to happen soon, it's not inconceivable that it might far in the future. Just how long it could take is unknown, but further studies of Venus could reveal the answer, however unnerving it might be.

Neil deGrasse Tyson

How one man rewrote the rules on making science fun

In this day and age, science communication is more important than ever. We live on the cusp of greatness, but many complex topics remain unexplained or misunderstood by the general public.

That, though, is where Neil deGrasse Tyson comes in. Not many astrophysicists take the time to host a mainstream show about space while also engaging with people who believe Earth is flat. But that's exactly what Tyson does – and he does it with aplomb.

If you recognise Tyson, that's no surprise. He's an outspoken and popular astrophysicist, and he hosted NBC's *Cosmos* show – a successor to the late Carl Sagan's 1980 show of the same name – in 2014, while also appearing on other popular TV shows. He's written books, appeared in movies, hosted podcasts – you name it. Tyson is one of the great science communicators of our time.

From an early age he was fascinated by astronomy. Born in Manhattan on October 5, 1958, almost exactly a year after the Soviet Union's Sputnik 1 became the first man-made

> "Tyson is one of the great science communicators of our time"

satellite to orbit Earth, Tyson's love for astronomy blossomed when he visited the Hayden Planetarium in New York at the age of nine. After attending Harvard College and the University of Texas to study physics and astronomy respectively, Tyson's life in astronomy came full circle when he joined the Hayden Planetarium in 1994 as a staff scientist, before becoming its director in 1996.

He oversaw a complete revamp of the facility after becoming director, with the $210 million project being completed in 2000. However, his time at the helm was not without controversy; he felt the full brunt of the public's ire after essentially declaring Pluto was not a planet in one of his exhibits. By 2006, the International Astronomical Union had followed his lead, and demoted Pluto to dwarf planet status.

A LIFE'S WORK

A closer look at the life of Neil deGrasse Tyson, one of science's great modern communicators

1958
Neil deGrasse Tyson is born in Manhattan, New York City on 5 October 1958.

1980
Tyson earns a bachelor's degree in physics from Harvard University.

1983
Tyson graduates from the University of Texas at Austin with a masters in astronomy.

1996
Tyson becomes the director of the Hayden Planetarium, having joined as a staff scientist two years earlier.

The Hayden Planetarium is found at the American Museum of Natural History

2000
Tyson courts controversy when his revamp of the planetarium does not name Pluto as a planet.

The big idea

People like Tyson bring science to the masses

How many people have been the director of a planetarium, appeared on popular shows like *The Big Bang Theory* and *Family Guy*, and even received the NASA Distinguished Public Service Medal? There certainly aren't many we can think of...

Well, Neil deGrasse Tyson is one of those people, although if there's another, we'd love to hear it. He's a great outspoken proponent of science, and although he's had his fair share of controversy, the world needs people like Tyson.

And let's not forget that he was named *People Magazine*'s Sexiest Astrophysicist Alive in 2000! If you haven't seen Tyson in the 2014 reboot of *Cosmos* yet, or enjoyed one of his *StarTalk* shows on YouTube, we'd highly recommend doing so.

Tyson is also known for his writing, having penned a number of books on astronomy including *One Universe: At Home in the Cosmos* and *Death by Black Hole: And Other Cosmic Quandaries*.

Today, though, you might know him better for his frequent appearances in the public eye, particularly on Twitter, where he is an outspoken defender of science. In early 2016, he got into a somewhat bizarre public spat with a rapper who was adamant that Earth was flat, claims that were easily debunked by Tyson. And he's also well known for offering his critique on popular science fiction movies like *Gravity*, *Interstellar* and *The Martian*.

Science communication is more important than ever right now, and thanks to people like Neil deGrasse Tyson, we have powerful voices teaching the public about the amazing universe around them.

Tyson has made a number of appearances on TV including in *Brooklyn Nine-Nine*, pictured

Tyson is seen here with science presenter Bill Nye and President Obama in 2014

Five things to know about... NEIL DEGRASSE TYSON

1 An asteroid is named after him

Located in the asteroid belt, the space rock in question is called 13123 Tyson, and was renamed in his honour in 2001.

2 He studied exploding stars

Tyson has participated in many pieces of research, noticeably on different types of supernova, and how they can be used to measure distances in the universe.

3 He was appointed by the President

In 2001 and 2004, Tyson worked for President George W Bush, debating policy for US space exploration going forward.

4 He fixed the stars in Titanic

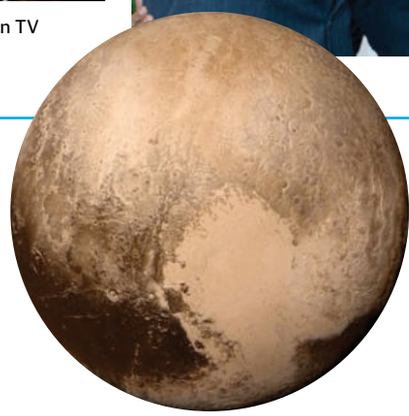
One of Tyson's famous critiques of a movie was *Titanic*, which he said they depicted the wrong night sky during the ship's sinking. This was changed in a re-release.

5 He met his hero

One of Tyson's inspirations was Carl Sagan, who sent Tyson a letter when he was 17 and invited him to tour his lab. They remained in touch after.

2004
Tyson hosts a four-part miniseries on PBS called *Origins*.

2004
Tyson is awarded the NASA Distinguished Public Service Medal.



Pluto was visited by the New Horizons mission in 2015

2006
The International Astronomical Union follows Tyson's lead and demotes Pluto to a dwarf planet.

2009
Tyson launches a radio talk show called *StarTalk*, which later becomes a YouTube and TV series.

2014
Tyson hosts the reboot of Carl Sagan's popular *Cosmos* series, called *Cosmos: A Spacetime Odyssey*.

An interview with... Neil deGrasse Tyson

Neil deGrasse Tyson has helped popularise science with his engaging and informative television shows and podcasts

Our sister magazine **All About Space** spoke to Neil earlier this year to discuss his StarTalk podcast, a simulated universe and more

Over the years, you've gained a reputation for helping to make science and space accessible to the wider population. How do you go about hitting the right spot for people – what do you think grabs their attention?
I've thought a lot about what might interest a disinterested person and I have thought more about the impact of what I'm saying than you can possibly believe. I could say something off the cuff, and you'd say, "Oh man that's really cool, that's great, how have you just figured that out?" And I'd think, "No, I've thought about this and I've watched you react to things I've said – I know what you're going to find interesting." When I'm talking to people, I'm looking to see if they've raised their eyebrows or if they look bored or excited. I have a mental inventory of things that enchant and bore people and the things that people want to hear more of. I bring that to my lectures, books or *StarTalk*.

Let's discuss *StarTalk*. The podcast has been around since 2009, but where did the idea come from and what was your aim?
Three of us started the concept. Myself and my co-executive producers Helen Matsos, who is a NASA astrobiologist, and David Gamble got together and realised there was an unserved population out there who, in our judgement, would enjoy science but didn't know that they would. We figured there was a population that does not buy science books or write on the calendar when a science programme is coming on television – people who are kind of oblivious to it. And we thought we might be able to create a media product that would attract them. But in addition to that, we realised there was a demographic of people who are sure that they do not like science. Maybe they didn't do well in their science class and they spent the rest of their life avoiding it. We thought we might be able to reach to them as well. So *StarTalk* became a synthesis of pop culture, science and comedy.

Tyson has hosted several StarTalk Live! Events, covering topics such as climate change, gravitational waves and the exploration of Mars

Why did you go for that mix?
Well, we realised that if you attach science to pop culture, you don't have to explain the pop culture parts. People know the famous actor, the famous singer or famous politician and if they become my guests, and if my conversation with them explores science, then fans will follow them to the show and we get to expose people to science and show them how ubiquitous science is in their lives. We get to show them that it's even touching their favourite person. So in the studio, I have my co-host, a professional comedian, and I typically bring in an academic on a particular subject that we cover in the interview with the pop culture person. The comedian is a valve of levity and the expert is a valve of gravity and I control those valves in such a way so that the listener can get, in my judgement, the right balance of science, as it appears in everyday life. And you end up smiling along the way. So this was an experiment and we proposed this to the National Science Foundation and they agreed it would be interesting.

You're not afraid of tackling some big ideas of space. We noticed recently that you said the universe could be a simulation. Why do you think that's the case?
So I was slightly misquoted there and, you know, headlines take liberties and they become click bait for others if you're surfing the internet. What I said was that I think it would be really cool if we were some alien simulation, maybe someone's PhD thesis experiment. It would be like, "I wonder what would happen if we set up these laws of physics and these laws of chemistry and biology and let's watch." And then I wonder if the aliens would start getting bored and start to throw in things to disrupt what might be a peaceful, tranquil world. But there are serious, philosophical questions and conversations about physics being conducted around this.

If we were in a simulation, do you think we would be able to tell?
One of my favourite references to this was from a colleague of mine, Max Tegmark who is a professor of astrophysics at the Massachusetts Institute of Technology. He said to imagine you're playing a game of *Mario* – any of the *Mario* video games – and let's say you are in the game. You start taking measurements and you say, "Okay, if I jump, I jump this high and the other characters don't jump as high as I do." So you start setting up laws of motion that apply inside the game and eventually you might figure out all the laws of motion and that is your world. But is that anything different to what we're doing with our branches of science? We're trying to figure out the laws of nature. Well, where do those laws come from? It's still a little bit of a mystery. Religious people would say God made the laws but if you're more prone to secular accounts of things, you might ask are these coming about naturally or by hand, by someone who has created our world for their own entertainment? And then you get deeply philosophical and say if we are a simulation of some super intelligent alien species, is that indistinguishable from the concept of God? That's another interesting topic to have a debate over a beer at a bar on, something to start arguing about, because everyone is going to have an opinion, no matter how much or little research they have done on the subject.

To read the interview in full, check out Issue 54 of All About Space, available now from imagineshop.co.uk and greatdigitalmags.com

Next-gen rocket engine

Meet SABRE, the revolutionary engine that could make spaceflight easier and cheaper

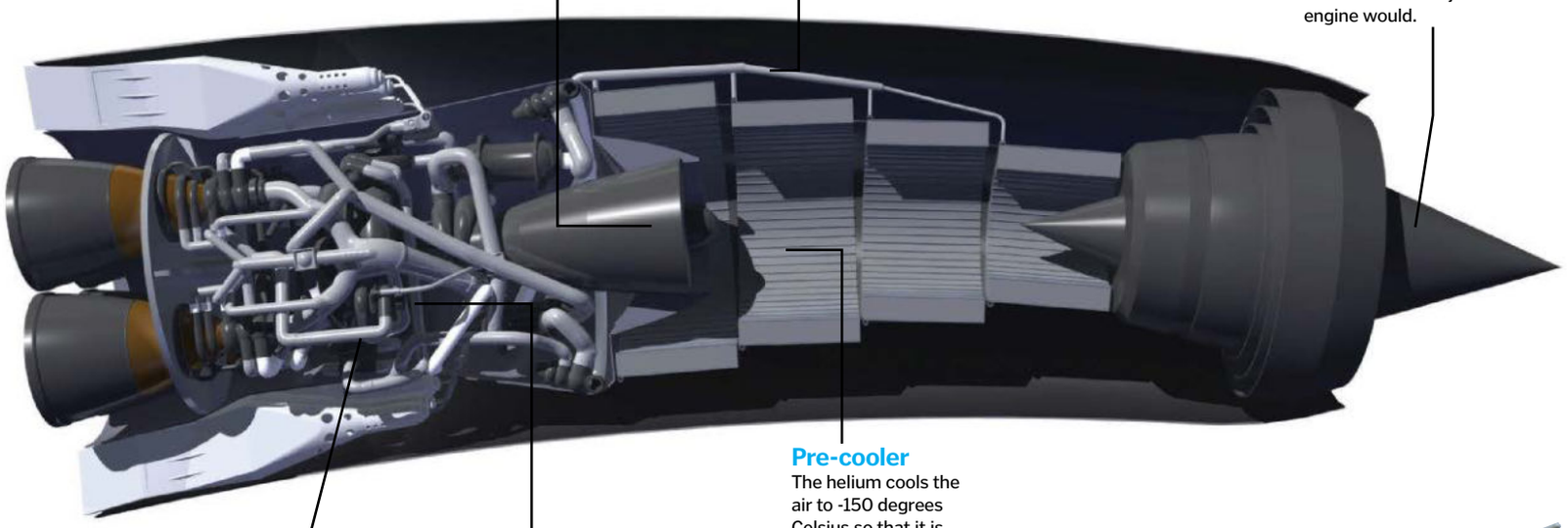
For conventional rockets to be able to launch into space, they must carry many tons of liquid oxygen in order to combust their fuel. This results in heavy, single-use rockets that must dump their empty fuel tanks to reduce weight as they ascend. In order to create reusable space planes that will be able to ferry tourists into and out of Earth's orbit, a new solution is needed, and British aerospace company Reaction Engines Ltd (REL) has an innovative answer.

The Synergetic Air-Breathing Rocket Engine (SABRE) can operate as a typical jet engine in the Earth's atmosphere, using oxygen from the air to burn with its liquid hydrogen fuel, and then becomes a rocket engine when it reaches an altitude of 25 kilometres, using the small amount of liquid oxygen fuel stored on board. Not only does this reduce the fuel payload by over 250 tons, but it also eliminates the need for empty fuel stages to be jettisoned during the launch, so the engine could be used to create reusable launch systems.

There is one major problem with creating an air-breathing rocket engine designed to travel at five times the speed of sound. The air being sucked in from the atmosphere at these speeds must be compressed before it reaches the combustion chamber, raising its temperature to 1,000 degrees Celsius, which would melt the engine's metal components. To solve this issue, REL has developed a cooling system, which cools incoming air to -150 degrees Celsius in less than one hundredth of a second. This would normally present another problem, as such low temperatures would cause moisture in the air to freeze, clogging up the engine. However, the team has also developed new technologies to stop frost from forming inside the engine.

Inside SABRE

A new class of engine with both air-breathing and rocket modes



Compressor
The cooled air is compressed to the required pressure, around 140 atmospheres.

Helium circulator
Liquid hydrogen fuel is used to cool helium, which circulates around the engine through pipes.

Intake cone
In the Earth's atmosphere, the engine sucks in air just as a conventional jet engine would.

Pre-cooler
The helium cools the air to -150 degrees Celsius so that it is almost a liquid.

Combustion chamber
The oxygen from the air burns with the liquid hydrogen fuel to drive the engine turbines.

Liquid oxygen fuel
When the aircraft leaves Earth's atmosphere and there is no more surrounding air, stored liquid oxygen fuel is used instead.

The Skylon spaceplane

SABRE has been designed to power Skylon, Reaction Engine Ltd's reusable spaceplane concept. Still in the early stages of development, Skylon will be capable of taking off from a reinforced runway and reaching five times the speed of sound to deliver up to 15 tons of cargo into space. Once in orbit, it will travel at 25 times the speed of sound, before re-entering Earth's atmosphere and landing back on a runway. In its current configuration, the plane will be able to carry up to 30 passengers to an altitude of 300 kilometres, all without the need for an onboard pilot.

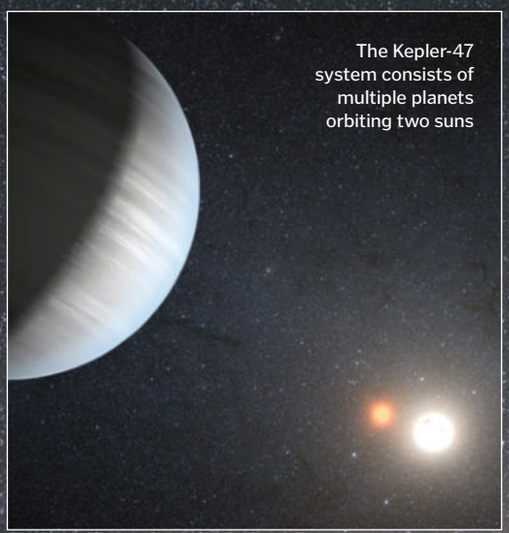
The Skylon spaceplane will be 82m long, with a wingspan of 25m

Multiple star systems

Unlike our lonely Sun, some stars have a companion to orbit

The Sun may be the only star in our Solar System, but over 80 per cent of the stars you see in the sky belong to multiple star systems, where two or more stars orbit each other. These systems typically emerge when star-forming clouds of gas and dust split to form multiple stars, but can also be the result of one massive star capturing others in its orbit.

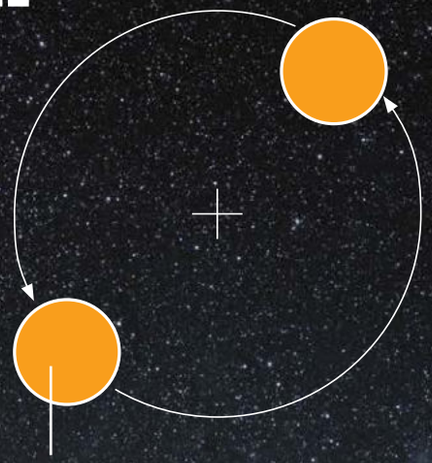
The most common examples are those with two stars, called binary systems, and their orbits can differ depending on the mass of each star. If a system contains three or more stars, the orbits become even more complicated.



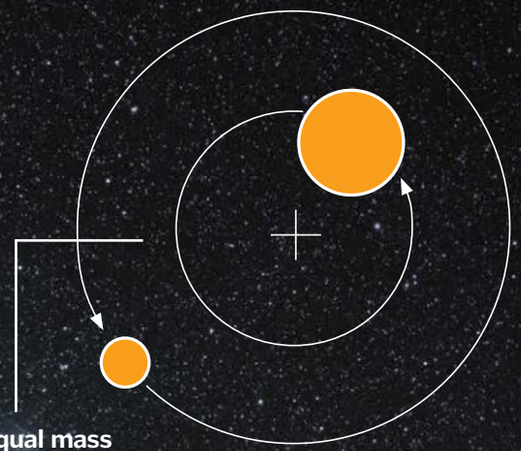
The Kepler-47 system consists of multiple planets orbiting two suns

Complex orbits

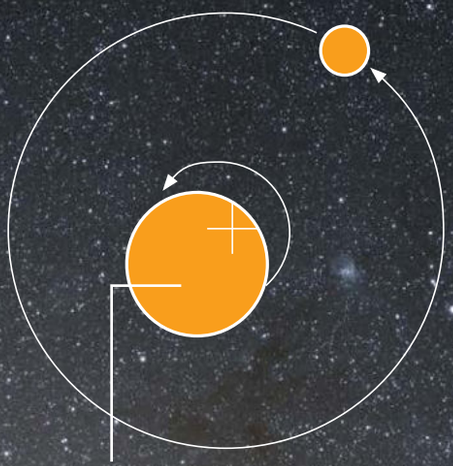
Discover how stars dance around each other in space



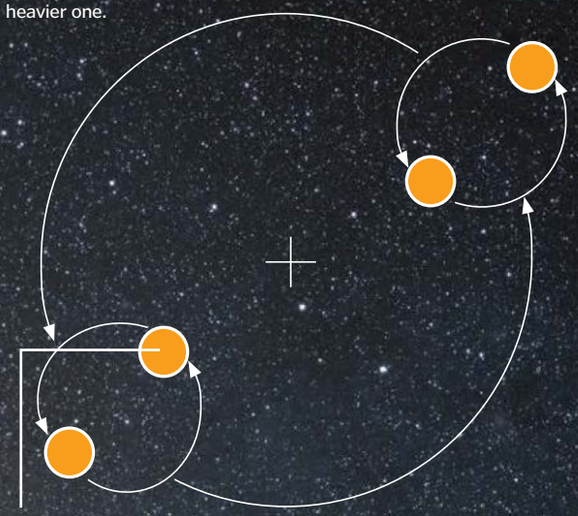
Equal mass
When two stars have the same mass, they orbit the centre of gravity located midway between them.



Unequal mass
If the stars have different masses, the centre of gravity lies closer to the heavier one.



Hugely unequal mass
If one star is much heavier than the other, the centre of gravity may lie on the heavier star's surface or even inside it.



Double binary system
In a system of four stars, each star orbits a companion, and the two pairs orbit the centre of gravity located between them.

The ISS bathroom

A specially designed toilet is required for astronauts to boldly go

Going to the bathroom is one of many everyday activities that are much more challenging for astronauts aboard the International Space Station (ISS). Water doesn't flow in microgravity, so it's not possible to have a standard flushing toilet. Instead, the ISS's toilets use airflow to get rid of waste.

For urine, each astronaut has their own personal funnel, which attaches to a tube on the toilet. For solid waste, a collection bag is placed in the toilet bowl. In both cases, a vacuum is activated to mimic gravity, drawing waste away as the astronaut does their business.

Water is a precious resource on the ISS, so urine and other wastewater (such as sweat) is recycled. The space station's Water Recovery System collects and purifies over 90 per cent of wastewater to make it safe to drink again.

Solid waste cannot be recycled, so it is collected in a tank and ejected from the ISS to burn up in the Earth's atmosphere. However, scientists are considering potential ways that solid waste could also be made useful. For example, long-duration missions like trips to Mars could theoretically use this waste for radiation shielding within a spacecraft's walls!

Toilets on the ISS use suction to overcome the problems of going to the bathroom in microgravity

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How to make the ultimate sword

Discover the ancient art of forging a deadly weapon

Swords were the first tools designed solely to kill. There were other weapons before swords, such as spears, axes and knives, but they were all originally intended for other purposes before being adopted as instruments of war. The spear was originally made for hunting, the axe for chopping wood, while knives have many functions. But the sword exists only to kill people.

Initially, swords were as much status items as weapons. These first swords, appearing from around 3000 BCE, were forged from bronze, an alloy of copper and tin. As the technology required to forge bronze was still new, and bronze itself quite rare, these early swords were very uncommon, highly prized and a sign that the person carrying them was extraordinarily wealthy and powerful. One such example is the bronze sword, shaped like a sickle, that was buried with Tutankhamun circa 1327 BCE. Called a khopesh, the sword of the pharaoh was sharpened on its outside edge, with the tip used both as a hook and a club.

The technology to make bronze spread around the Mediterranean basin, and trade evolved to bring tin from mines in the Iberian Peninsula and Cornwall to the forges of the eastern Mediterranean. As a result, swords became more and more widespread, until whole armies carried them. The Minoan, Sumerian and Assyrian empires were all carved out by armies carrying bronze swords.

But iron changed everything. The metal itself is common, strong and durable, and will produce a weapon that is both flexible and tough. The Hittites were early adopters of this technology, using iron weapons to form their empire from 1600 BCE onwards. With the Hittites showing the way, iron became the new material from which to forge swords.

The problem with iron swords, though, is that iron bends. To make a sharp, hard, cutting

edge, you need steel – an alloy of iron and carbon. In the first millennium BCE, the Etruscans began to create alloys of steel and iron, making swords that had edges hard enough to cut through armour, yet which were also sufficiently flexible to withstand the shock of battle.

The Romans developed Etruscan technology, creating the blade that characterised the Roman military machine: the gladius. This short, stabbing sword was the weapon of the legionary and, armed with it, the Romans created their empire. But it was the longer sword employed by their cavalry, the spatha, that outlived Roman rule. As the Western Empire declined, many of the barbarian groups who were employed to defend it used the spatha. The weapon became the prototype from which the swords of the Anglo-Saxons and Vikings, the high points of western sword making, developed.

Perhaps the finest example of these swords is the one found at Bamburgh in Northumberland. Excavated in 1960 and rediscovered in 2001 (just in time, as it was about to be thrown into a skip), the Bamburgh Sword was forged in the 7th century. About 76 centimetres long when first made, the sword was passed down through the centuries until, some 300 years after it was forged, it broke. As an heirloom of kings and earls, the sword was not thrown away, but buried, until archaeologists excavated it, although at first they did not realise what they had found.

The Bamburgh Sword was made from six strands of iron, pattern-welded together. No other sword has been found with more than four. In pattern welding, the iron strands are heated, twisted and hammered together, over and over again. When finished, pattern-welded swords have striking swirling designs on them.

It was this tell-tale pattern that led, in part, to the end of pattern-welded swords. Every warrior wanted a weapon like this and, by the later Viking Age, armies had grown to a thousand or more men. In response, crafty swordsmiths began producing fake versions of these blades, which had an ordinary iron core and a thin pattern-welded layer on top.

With the arrival of massed armies, swordsmiths started to forge simpler, easier-to-make blades. The design of the swords continued to change through the following centuries, to suit the fighting styles of the men carrying them. Blade styles also changed as armour improved, making it harder to cut through with a sword's edge. As a result, the point of the sword became more important, being sharpened and hardened so that it could punch a hole through an enemy's armour. Despite bullets largely replacing blades on battlefields, swords continued to be employed by soldiers into the 20th century, being used widely during the Russian Civil War (1918-1920) and the Sino-Japanese War (1937-1945).

A historical reenactor dressed as an Anglo-Saxon warrior, armed with sword and seax

Blades through the ages

Gladius

The sword that conquered the world. This was the sword of the Roman legions, designed for thrusting, and used when standing in phalanx (rectangular) formation beside other legionaries.

Spatha

The sword that was used by Roman cavalry. It was in fact longer than the gladius and, in the later Empire, it gradually started to replace the gladius as the main infantry weapon.

Anglo-Saxon/Viking swords

These swords evolved from the spatha and were used for hand-to-hand combat after the shield wall broke down. Anglo-Saxon and Viking smiths perfected the design, making some of the finest swords in history.

Claymore

This was an intimidating two-handed sword used in Scotland from around 1400 to 1700. It was approximately 140 centimetres in length, making it a terrifying presence on any battlefield.

Rapier

The rapier was a sword carried by civilians in the 16th and 17th centuries. It was designed for self-defence, and used in brawls and duels. Modern fencing has developed from the style of fighting used with a rapier.

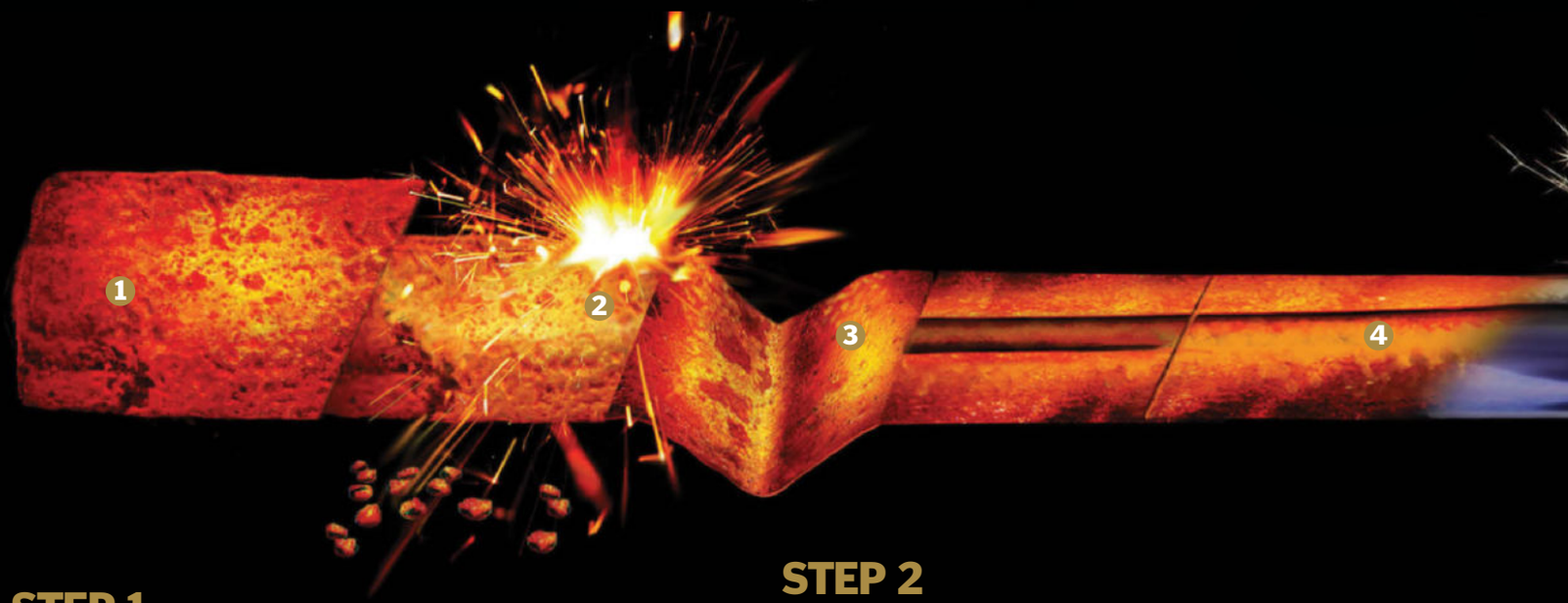
Sabre

The sabre is usually a curved, single-edged sword used by cavalry in the Napoleonic Wars. However, sabres of the time could also be straight blades, used in thrusting attacks. Both were devastating against infantry.

Forging the blade

How to make the perfect killing machine

Swordsmiths through history have faced a big problem when making swords. Iron is flexible, and this makes it excellent as a blade, since it will bend when struck, rather than breaking in combat – half a sword is not much use in a battle! But because iron is malleable, it will not keep an edge, meaning that after half an hour's fighting, a pure iron sword will turn into something little better than a long club. Steel (an alloy of iron and carbon) is much harder, so it will keep its edge even after slicing through shields and armour. But steel is also brittle, making it vulnerable to sideways, parrying blows. A sharp steel sword will cut through almost anything, but a good whack with a wooden staff would probably break it. Through the centuries, swordsmiths have attempted to marry the strengths of steel and iron, and to minimise their weaknesses by forging swords with iron cores and steel cutting edges. Welding core and edge together was – and is – a hugely skilled process, and can go wrong at any stage if impurities concentrate at a point. This can be particularly upsetting for a swordsmith who has spent days hammer-forging a blade.



STEP 1

Choose your metal

The iron made the sword. Getting the best metal was the most important part of making a good blade. However, apart from the occasional meteorite, there is very little pure iron on Earth. For swordmaking, iron was often obtained from bogs or mined; bog iron is carried in liquid form into the bog, then concentrated by anaerobic bacteria, producing small lumps of iron. This source of iron is renewable, as new lumps appear in 15 to 20 years.

STEP 2

Forging

Forging is when the smith hits the hot metal with a hammer over and over again, working it into shape. The best swords fuse iron and steel, and heating the metals makes thousands of tiny welds, joining the two materials together. Forging also spreads any impurities evenly through the sword, reducing the chance of the weapon breaking. In the best swords, bars of good iron are twisted together, further spreading out any impurities. The bars are welded into a solid core, and the steel edge welded on to the core.

STEP 3
Annealing
As the swordsmith is forging the blade, they will usually return it to the heat several times, and let it cool again without working on it. This helps to reduce irregularities in the blade. Once it has been shaped, the sword is annealed by heating it to a precise temperature and allowing it to cool very slowly. This is done either by allowing the forge fire to cool, or by burying the sword in hot sand.

STEP 4
Grinding
Swordsmiths through the centuries have used different methods to grind the blade, from water-powered wheels to sand on leather, but hand files were the most common tools employed. The aim of grinding is to remove the material that cannot easily be removed by the forging process. The fuller – the groove down the middle of the sword – and any engraved designs are also added at this stage.

STEP 5
Hardening
The shaped sword is reheated until it glows a dull orange colour. At this heat, the metal becomes non-magnetic. The sword is then quenched in water. This helps to line up the crystalline structure of the iron and steel in the sword and makes it harder. But quenching can also make the sword brittle. To overcome this, smiths must heat the blade again, for the next stage in making the sword.

STEP 6
Tempering
To overcome the brittleness produced in the hardening, the sword has to be reheated to a lower temperature than before. In the days before temperature gauges, this was done by colour; the smith heats the sword until the edge is a straw colour, and the centre – with its thicker metal – a deep purple. The blade is then slowly cooled. This slow cooling reintroduces some flexibility into the sword, making sure it does not break in battle.

STEP 7
Completion
Although the sword is now forged, it looks dirty and crusted, so it has to be cleaned. Abrasives, such as sand on leather, are used to file and clean the sword, until it is ready for sharpening on a whetstone. After a final sharpen, pattern-welded swords are etched to highlight the pattern on the blade. The most impressive swords have hilts made of precious metals, with jewels inset, while the pommel and guard are adjusted to keep the weapon balanced. The sword is now ready for use.

DID YOU KNOW? *Conquistadors introduced diseases like smallpox to the New World*

Anatomy of a Spanish conquistador

How a small army of Spaniards brought an entire civilisation to its knees

When Christopher Columbus discovered the 'New World' in 1492, many Europeans dreamt of finding fame and fortune there. The Spanish, French and British Empires sponsored various expeditions, but many mercenaries also took it upon themselves to seek riches even if they weren't sanctioned by the Crown.

Spanish explorer Hernán Cortés was driven by the promise of wealth and power, and in 1519 led 500 conquistadors ('conquerors') on a mission into modern-day Mexico. After a three-month trek, the army arrived in the Aztec capital of Tenochtitlán, where Cortés captured the Aztec king, Montezuma II.

At first, the Aztecs were successful in driving the Spanish invaders from the city, but Cortés returned in 1521. On this second attempt, he overthrew the natives and took control of the city, despite his men being vastly outnumbered. It was one of the bloodiest battles in history, resulting in around 200,000 casualties. Clad in plate armour and armed with Toledo steel swords, the conquistadors' advanced weaponry was far superior to the stone or bronze clubs the Aztecs wielded. The Spanish were also equipped with canons and an early type of firearm known as a harquebus. When cavalry attacks were launched, the Aztecs had no way to counter them, having never seen horses before.

The Aztec Empire fell in 1521, and a new settlement, Mexico City, was built on the ruins of Tenochtitlán. The conquistadors ventured further inland, expanding Spain's influence as a global power in the Age of Discovery.

A Spanish conquistador

The equipment and weaponry that helped these soldiers dominate Central America

Helmet
A steel helmet protected against arrows or blows to the head.

Toledo steel swords
Made in the Spanish city of the same name, these blades were much stronger than any weapon created by the Aztecs.

Camisa
The long-sleeved shirt was comfortable, and allowed armour to easily be worn over it.

Armour
Some conquistadors were protected with steel breastplates, which the Aztecs' primitive weapons could not pierce.

Cuerra
Full armour was very expensive, so many men chose to wear a leather jacket, known as a cuerra, covered by a chainmail vest if they could afford it.

Shield
The shield had a convex design to help deflect blows, and was one-handed so the conquistador could also wield a sword.

The search for El Dorado

As the European empires delved deeper into the Americas, stories of a lavish city of gold began to appear. The legend of El Dorado inspired explorers to seek out the rumoured source of riches. The expeditions peaked between 1530 and 1560, but eventually ground to a halt as attacks from natives and the danger of long treks took their toll.

Legendary explorer Sir Walter Raleigh made two failed attempts to find El Dorado in Guiana. The second was fatal for Raleigh and his son. Watt Raleigh was killed in conflict, while Walter was executed on his return for attacking the Spanish against orders.

One of the most famous expeditions to find El Dorado was led by English explorer Sir Walter Raleigh

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	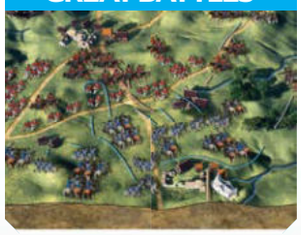		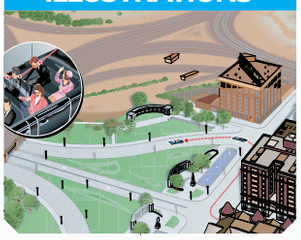	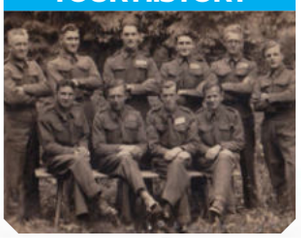

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A Roman legionary's lunch

Every army marches on its stomach, and the formidable Roman legions were certainly no different. Check out what foods fuelled the average soldier

Posca
Soldiers drank large quantities of posca, a drink made by mixing a sour wine with vinegar and water.

Pulmentum
A staple meal of the legions, this was a simple gruel made from barley.

Cheese
The Romans loved smoked cheese, and it was often eaten with bacon fat.

Meat
Salted pork and mutton were popular, as were more unusual meats, like hare, elk and even bear.

Fruit and vegetables
Olives, plums, figs and apples were all popular, and helped to keep scurvy at bay.

Bucellatum
These hard tack biscuits were a staple food for the legions. They were dry and salty so kept well during long campaigns.

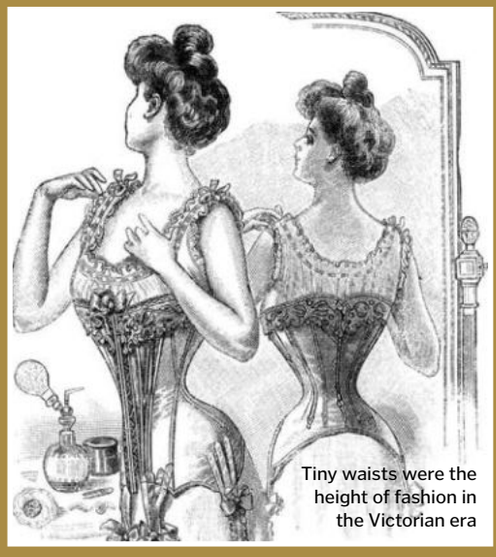
How corsets worked

The style craze that deformed bones and distorted bodies – all in the name of fashion

The corset is infamous for crushing women's waistlines into an hourglass shape. The garment's origins date back millennia, with early examples believed to have been worn in ancient Crete 3,000 years ago.

The waist-cinching trend peaked in the 19th century as hourglass figures became the focus of fashion. Victorian corsets were made from coutil, a fabric famed for its resistance to stretching. This was reinforced with strips of rigid materials, such as wood, whalebone or even steel to provide structure. Tight-lacing was commonplace, which involved someone (usually a servant or lady's maid) pulling the laces of the wearer's corset to achieve the smallest waist size possible.

Corsets were so fashionable that children were given training versions to prepare them for the torturous ordeal. This, along with women starving themselves to stay thin, was a dangerous combination. It is widely believed that corsets caused organ damage, but there is not enough evidence to know for sure. They did take their toll on women's bodies though: long-term use could distort the lower ribs and decrease lung capacity.



Tiny waists were the height of fashion in the Victorian era

Panning for gold

How the 49ers found fortune in the famous Californian gold rush

To try and strike gold, hopeful prospectors employed many different techniques

On 24 January 1848, James W. Marshall struck gold in Sutter's Mill, Coloma. The discovery didn't stay secret for long, and prospectors searching for big bucks soon arrived in their droves. The news first spread to nearby states, but later some 300,000 fortune hunters arrived from as far afield as China and Australia. Heading to California a year after the initial discovery, they were known as the 49ers.

At first, the gold was so abundant that flakes could be picked straight from the ground, but this easy source was quickly exhausted by the first waves of 49ers. Panning became a common method to find nuggets in rivers and streams, but as these too were gradually depleted, more intricate ideas were required. Wooden cradles were constructed with a sieve at the top to catch and search much larger amounts of rock and gravel at a time, while 'coyote mining' involved digging a deep shaft to reach the most plentiful supplies. The most complex system of all was hydraulic mining, which used high-pressure water to loosen potential gold seams from gravel beds. It was very effective, extracting an estimated total of 340 tons of gold by the mid-1880s.

How to pan for gold

A simple yet effective way to earn a fortune in the Old West

1 The rush for gold

It's first-come first-served in the hills of California, but every route has its dangers. Trekking over land involves perilous mountain passes, while journeys at sea are long and treacherous.

2 Choose an ideal location

Don't just settle down anywhere; pick a spot that has the best chance of gold. Ideally, find a clean, deep stream that has slow-running currents. Also watch out for fellow prospectors stealing your territory!

3 Start to pan

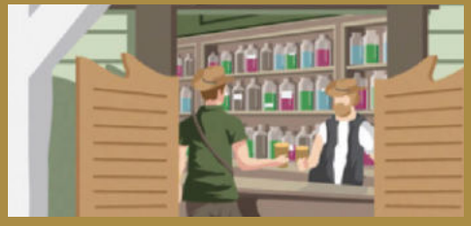
Panning is the simplest way to find gold. Swirl a mixture of water and dirt, and the heavier nuggets will sink to the bottom of the pan. The gold will rush downstream, so make sure you catch it before your rivals do!

4 Tools of the trade

The best prospectors can wash around 50 pans a day and also use knives and shovels to dig on dry land. As more money floods in, you can afford bigger and better extraction methods.

5 Find your reward

The process can take time, so it pays to be patient. Not all the gold will be in convenient, large nuggets, so make sure you search the gravel for small specks of the precious metal.



6 Spend, spend, spend

Every 49er spends their new wealth differently, whether it's setting up a business or hitting the saloon. After the gold began to run out, many prospectors returned home, but some stayed to live a new life in the West.

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds that her job comes in very handy for taking part in quizzes!

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*.

Disruption to their body clocks means that astronauts typically don't sleep well on the ISS

How do astronauts on the ISS sleep without floating around?

Andy Albright

Astronauts on the ISS fasten their sleeping bag to the wall or ceiling with Velcro straps to prevent themselves from drifting about in their sleep. Most crew members have their own individual cabin where they can listen to music, use their laptop and store personal belongings. Many wear an eye mask to block out the sunlight – the ISS witnesses 16 sunsets and 16 sunrises in every 24-hour period, so it is never dark for long. Ventilation is also very important, otherwise a bubble of carbon dioxide can form around the astronaut's head as they exhale. **AC**

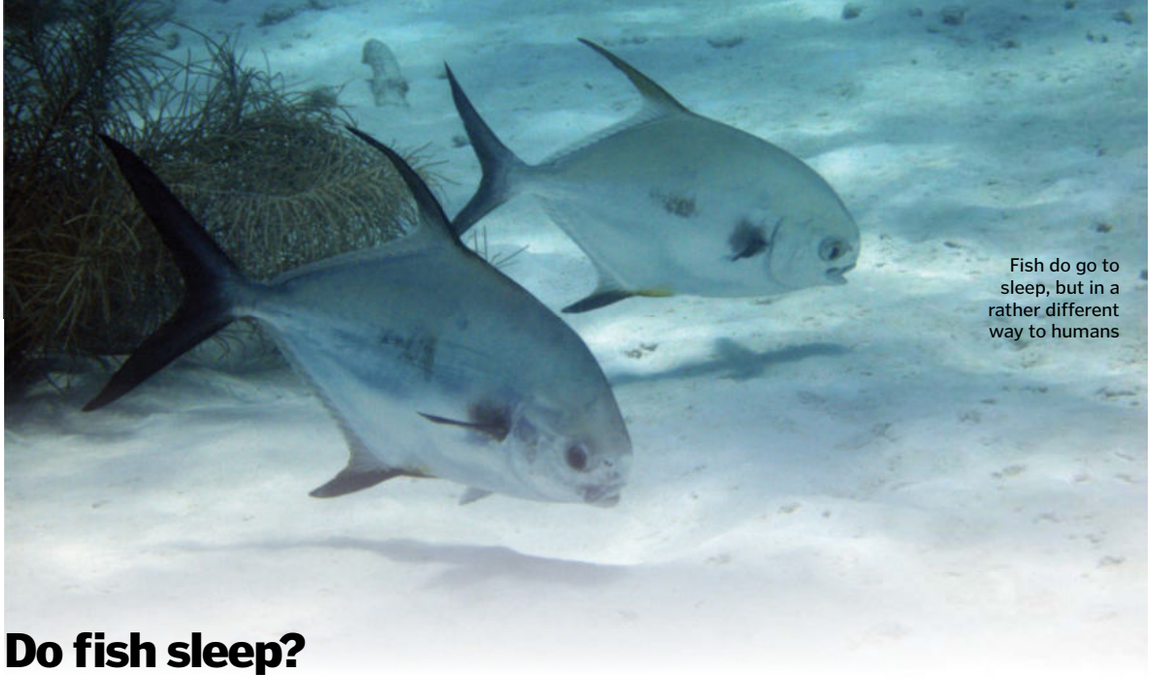
The amount of alcohol you drink matters more than the type of drink

Why does mixing alcoholic drinks make you ill?

F. Forster

There are lots of theories on why mixing different alcoholic drinks might make you sick. There are different chemicals in different types of alcoholic drinks that influence the speed of absorption and the severity of a hangover. These include bubbles, sugar and compounds known as 'congeners', and different drinks are known to affect people in different ways. However, the real risk is drinking too much.

Once you've had a few alcoholic drinks, your ability to judge your own drunkenness decreases, and if you've mixed drinks, you've probably had more than one or two. The more alcohol you take in, the more likely you are to get ill. **LM**



Fish do go to sleep, but in a rather different way to humans

Do fish sleep?

Thomas Barker

Fish do sleep, and the amount of sleep a fish gets depends on various factors, such as light conditions and how active it has been. However, it might not be obvious when a fish is sleeping. For a start, fish don't have eyelids, so their eyes appear to be open even when they sleep. They also don't experience rapid eye movement (REM), which defines how mammals sleep. But, although many question whether fish really do sleep, their trance-like state is evidence that they do. When a fish goes to sleep, it may settle at the bottom of its habitat, and some even keep moving. **SB**

The sand in the Sahara is a result of rock erosion and weathering

Where did the sand in the Sahara Desert come from?

Tom Brower

The original source of the sand found in the Sahara Desert is the large mountain ranges in the centre of the Sahara. These volcanic mountains left behind sand grains when the granite rock eroded and weathered. Rivers then transported the sand grains to the sea, where they formed into sandstone. Further weathering turned them into sand again. It is believed to take tens of thousands, perhaps even millions, of years for exposed rock to weather into sand. The sand in the Sahara is thought to have existed for seven million years. These days, only around ten per cent of the Sahara is covered in sand, though. Most of it is actually rocky plateaus. **SB**

Does chewing gum really stay inside you for years?

Isobel Thornton

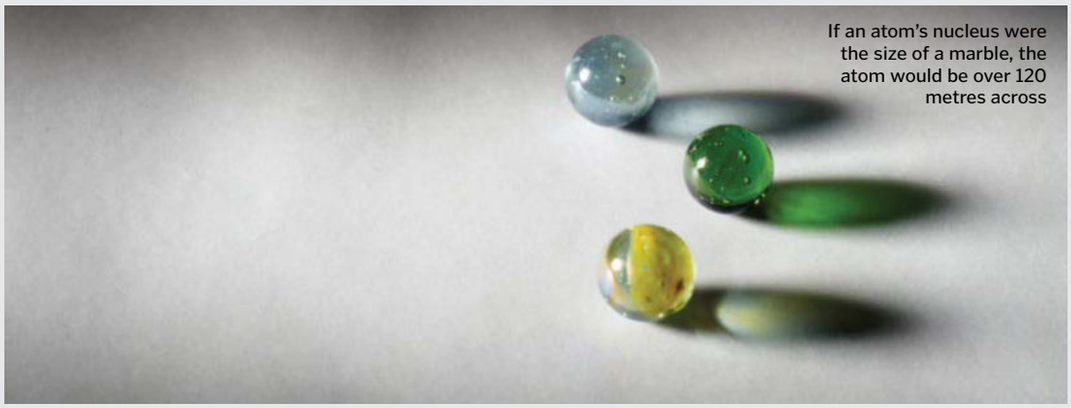
The old rumour goes that chewing gum stays in your stomach for seven years if you swallow it, but in truth, it usually passes through the digestive system in a matter of days.

The chewy component of chewing gum is made from a combination of man-made polymers, waxes and softeners; these are difficult for the body to break down. However, the squeezing and pushing action of the muscles in the walls of the stomach and intestines still manage to move it through the system.

Swallowing a piece of gum occasionally is unlikely to do you any harm, but swallowing lots could be dangerous. There have been reports of children with blockages in their intestines caused by swallowing huge quantities of it. **LM**

Chewing gum is made from synthetic chemicals that the body can't break down

BRAIN DUMP



If an atom's nucleus were the size of a marble, the atom would be over 120 metres across

If a nucleus were the size of a marble, how big would the atom be?

Dan Carpenter

An atom's diameter is roughly 10,000-100,000 times that of its nucleus, so if the nucleus were the size of a marble, the full atom would occupy a sphere with the diameter of a football pitch's length (120 metres) or as much as ten times this. An actual nucleus is about 10^{-15} metres across, while an atom is in the order of 10^{-10} metres, with its outer limits defined by the distance at which the furthermost electrons orbit the nucleus. The nucleus is incredibly dense – if the nucleus was the size of a marble, it would weigh about 105 tons. The electrons have only 1/1800th of the mass of a proton or neutron, and as they orbit over a relatively large distance, most of an atom is actually just empty space! Electrons do not have clearly defined orbits, but are often visualised as a 'cloud' showing the probability of different electrons' positions. **AC**

Calculators translate numbers into binary code to come up with an answer

How does a calculator work?

Sara Cesare

When you press the buttons on a calculator, you connect circuits. Electricity from the calculator's battery travels along the circuits to a transistor. These switches have two positions: zero for off and one for on, and represent the language of computers, in which every number has an equivalent binary code – a combination of ones and zeros. The calculator combines the codes stored in the transistors using an electronic circuit called a logic gate. This compares inputs, then sends out a new current based on its findings. The type of logic gate used depends on if you've asked the calculator to add, subtract, multiply or divide. Even a simple equation requires multiple logic gates, but when you use a calculator, this complicated process seems to happens in an instant. **SF**

FASCINATING FACTS

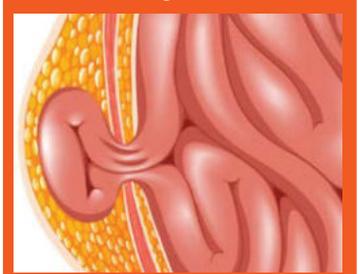
What is a light year?

A light year is simply a unit of astronomical distance equivalent to the distance that light travels in one year, which is approximately nine trillion kilometres. **SB**

Light travels approximately nine trillion kilometres in one year

What is a hernia?

A hernia occurs when a weakness in a muscle wall allows an organ or tissue to protrude. The condition usually results in a lump or bulge in the abdomen or groin area. **AC**



The most common type of hernia involves the intestines pushing through a weak spot in the lower abdomen area

How long is a day on planet Mercury?

A day on Mercury is much longer than a day on Earth, lasting 59 of our day lengths. However, a year on Mercury is much shorter, at just 88 Earth days. **LM**

Days and nights on Mercury are long, and temperatures are extreme

Never look at the Sun unless you are using specially designed glasses that are intended for this purpose

Why does looking at the Sun damage your eyes?

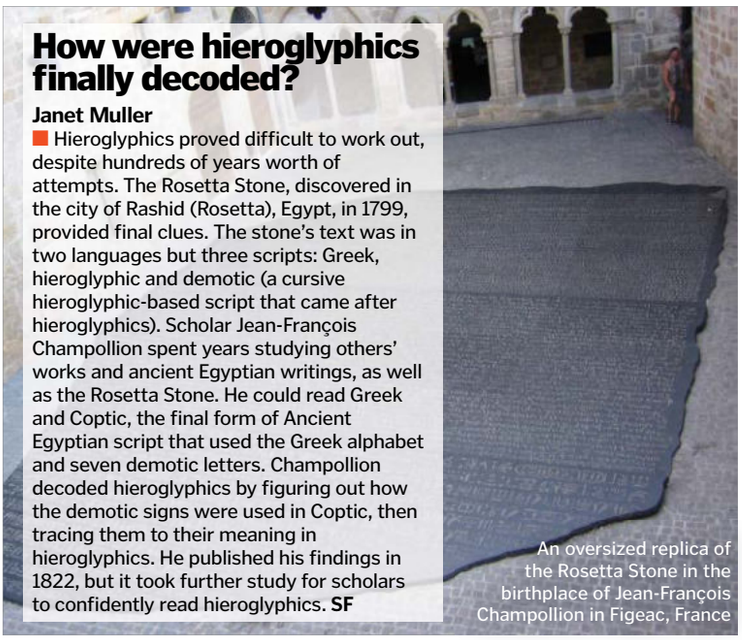
Tom O'Malley

The Sun's light contains far more energy than our eyes can safely absorb, and it can damage the eye's delicate structures very quickly. Staring directly at the Sun for a few seconds typically causes photokeratitis, a condition that is similar to sunburn, which leads the cornea to become cracked and inflamed. Though it is very painful, patients usually recover fully. Longer exposure can damage the retina, causing vision to become blurry or discoloured for several months, and eyesight may never completely return to normal. Damage to the macula, a portion of the retina used for detailed vision, can result in permanent loss of visual acuity. **AC**

How were hieroglyphics finally decoded?

Janet Muller

Hieroglyphics proved difficult to work out, despite hundreds of years worth of attempts. The Rosetta Stone, discovered in the city of Rashid (Rosetta), Egypt, in 1799, provided final clues. The stone's text was in two languages but three scripts: Greek, hieroglyphic and demotic (a cursive hieroglyphic-based script that came after hieroglyphics). Scholar Jean-François Champollion spent years studying others' works and ancient Egyptian writings, as well as the Rosetta Stone. He could read Greek and Coptic, the final form of Ancient Egyptian script that used the Greek alphabet and seven demotic letters. Champollion decoded hieroglyphics by figuring out how the demotic signs were used in Coptic, then tracing them to their meaning in hieroglyphics. He published his findings in 1822, but it took further study for scholars to confidently read hieroglyphics. **SF**



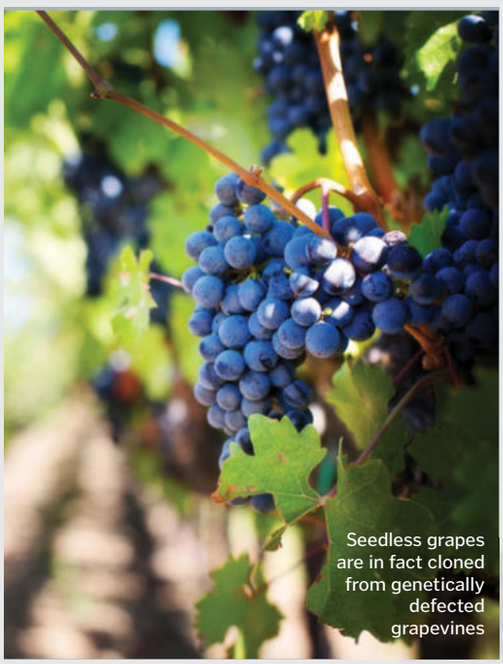
An oversized replica of the Rosetta Stone in the birthplace of Jean-François Champollion in Figeac, France

Why does it hurt so much when you step on a plug?

Tom Granger

Plugs are made from metal and plastic and are designed to be seriously strong. When you put your full weight down on the pins, they don't bend and deform, they dig right in to the skin. The soles of the feet are highly sensitive, containing nerves that detect pressure and pain. When you take a normal step, the force is distributed across the sole of your foot, but when you come down on a hard object, like a plug or a Lego brick, the whole force is concentrated in a small area. Depending on how fast you were walking, and the position of your foot, this can be equivalent to several times your own body weight concentrated right over the end of the hard, metal pins. **LM**

Balancing your body weight on the pins of a plug puts huge pressure on your foot



Seedless grapes are in fact cloned from genetically defected grapevines

How are the seeds removed from seedless grapes?

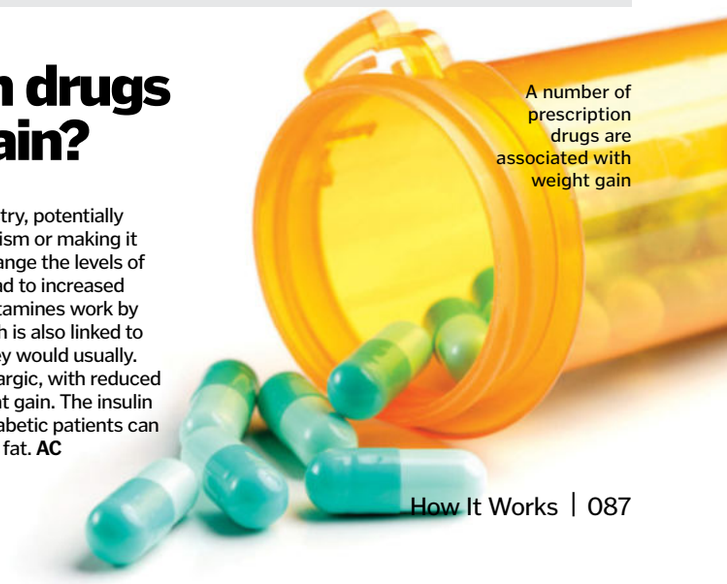
Lauren McElroy

The seeds aren't removed. We sometimes get genetically defected vines, from which the grapes don't produce seeds. If a cutting is made from this vine, dipped in a hormone that stimulates root growth, then placed in moist dirt, roots and leaves will form. The new vine will produce more seedless grapes, and so the process continues! So seedless grapes haven't been reproduced from seeds, but have been cloned. They contain the beginnings of seeds, but the genetic mutation means they never form the hard outer shell. **SB**

How can certain drugs cause weight gain?

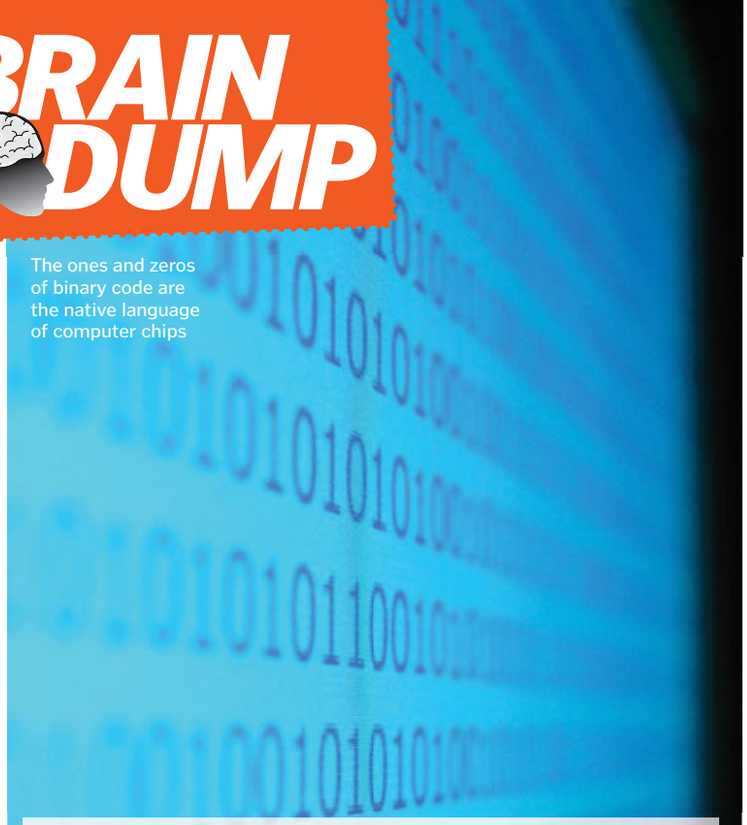
George Crooks

Medications affect brain and body chemistry, potentially making you hungrier, affecting your metabolism or making it harder to burn calories. Anti-depressants change the levels of certain chemicals in the brain, which may lead to increased appetite and food cravings. Likewise, antihistamines work by suppressing the H1 histamine receptor, which is also linked to satiety, leading patients to eat more than they would usually. Beta blockers can cause patients to feel lethargic, with reduced physical activity sometimes leading to weight gain. The insulin prescribed to control blood sugar levels in diabetic patients can encourage the body to store more energy as fat. **AC**



A number of prescription drugs are associated with weight gain

BRAIN DUMP



The ones and zeros of binary code are the native language of computer chips

Why do computers use binary code?

Aaron Taylor

Binary code is a way of representing data or instructions using just ones and zeros, and is the native language of computers. This is because the chips that computers are made of contain billions of tiny electronic switches called transistors. Like other switches, these have two settings, either on or off, or to put it another way, one or zero. So deep down, the electronics inside computers can only understand binary. Everything that you do on a computer has to be converted into binary for the computer to process, and then converted back into the output that you can see on the screen. **TL**

Common table salt doesn't clump thanks to the addition of anti-caking agents

Why don't grains of salt stick together?

Edward King

Grains of salt actually do tend to stick together because salt is hygroscopic, meaning that it absorbs water. However, the 'stickiness' depends on the shape of the grains, which varies between different types of salt. Common table salt has been highly refined to remove all impurities, giving it a uniform flavour, colour and texture. The grains are cube-shaped with flat surfaces that easily stick together. To combat this, manufacturers add an anti-caking agent to absorb moisture and prevent clumping. Other types, like sea salt or kosher salt, may or may not stick together depending on the shape of the crystals, how heavily processed they are, and whether they include an anti-caking agent. If you find your table salt clumping anyway – which can happen in a humid environment – adding a few grains of rice to the shaker can help to absorb moisture and get things flowing again. **SF**

Circles have 360 degrees due to the Sumerians' observations of the Sun's motion across the sky

Why are circles 360 degrees and not a round number?

Jon Evans

Some believe a circle should be 100 degrees, as we use a base-10 mathematical system in most cases. We got the system from people who studied the Sun thousands of years ago. Around 2400 BCE, Sumerians noticed that the Sun took roughly 360 days to complete a circuit through the sky. They divided the circular path into 360 degrees to correspond with each day. Later, Egyptians divided days into 24 hours. Babylonians then divided each hour into 60 minutes and each minute into 60 seconds for a base-60 system in around 100 BCE. **SF**

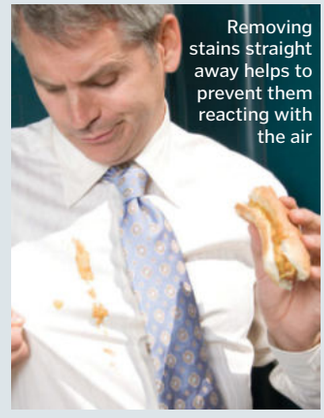
Why do oily things stain clothes?

Claire Lincoln

Oils leave behind dark, unsightly marks. Synthetic materials, like acrylic and polyester, are vulnerable because the grease is absorbed deep into the man-made fibres.

Oil doesn't dissolve in water, so simply running a greasy patch under the tap won't help, and the longer the oil is left on the fabric, the harder it is to remove. Oils can react with the air in a process called oxidation, resulting in tough yellow-coloured stains.

There are chemicals that pull grease away from fabric, including organic solvents to dissolve the oils, and enzymes, which 'eat' through fats. Many 'stain remover' products you can buy contain surfactants. Surfactant molecules are tadpole-shaped, with a head that sticks to water molecules, and a tail that binds to oils. They act as a chemical bridge, helping to pull oils away from clothes and into the water. **LM**

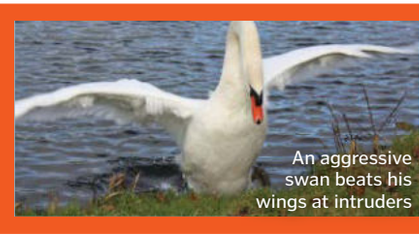


Removing stains straight away helps to prevent them reacting with the air

FASCINATING FACTS

Is a swan really capable of breaking someone's arm?

Male swans, especially when protecting a nest, can be very aggressive. However, a blow from their wings is unlikely to be strong enough to break an adult's arm. **SF**



An aggressive swan beats his wings at intruders

Data roaming enables you to connect your smartphone to the internet when you are in other countries

What is data roaming?

Victor Roberts

If you want to go online on your smartphone abroad, other countries aren't covered by your mobile network. They will have agreements with foreign mobile companies to allow their customers to connect to other networks as a guest. When you arrive in another country, a local network identifies your phone as belonging to a partner network, and connects you to the internet through their systems. **TL**

How much stronger is carbon fibre than steel?

Jake Harrison

Carbon fibre is a composite material made of thousands of tiny strands of carbon mixed with plastic. Like a rope made of many strands, carbon fibre is very strong. There are different types of both materials, but carbon fibre can be ten times stronger than steel. Despite this, it is very light, making it useful in aircraft. So why don't we use carbon fibre for everything? It's not just because it is expensive. Carbon fibre might be stronger than steel, but it isn't as stiff, and when it fails, it snaps rather than bends. Unlike metals, which are strong in all directions, carbon fibre is only strong in the direction in which the fibres within it are running. This means that designers have to be rather careful with how they use it, and for many uses, steel is a more suitable material, even if it isn't quite as strong. **TL**

Carbon fibre can be stronger than steel but is far lighter

Polarised sunglasses have filters that block some light waves while letting others through

How do polarised sunglasses work?

Sophie Mitchell

The lenses of polarised sunglasses are not just tinted glass, but treated with a layer of material that acts as a polarising filter. Light is made up of waves that travel vertically and horizontally. The polarising filter allows the vertically aligned light to pass through to your eyes, but it stops the horizontal light. This cuts down the total amount of light passing through the lenses, but also reduces glare too, because the light that bounces off shiny surfaces is mostly horizontal light, which gets blocked by the polarisation. **TL**

Why do toucans have such big beaks?

Lawrence O'Reilly

Does the toucan have a large beak to attract mates, as Charles Darwin believed? Is it used to warn off enemies? Or is it a tool for peeling fruits? Perhaps it's useful for all these things, but recent studies have found that the toucan has a big beak to keep cool in tropical climes. Scientists claim that even if its original function was different, this is the purpose it now serves. The large number of blood vessels along the surface of the beak means it radiates heat to stabilise the body's core temperature. Since the beak accounts for approximately one third of the bird's body length, it does this rather effectively. Scientists discovered that the toucan's beak was up to ten degrees Celsius warmer in the heat of the day than it was at sunset, and that it could adjust the flow of blood to its beak to control the amount of heat being conserved or lost. **SB**

Toucans have large beaks in order to regulate their body temperature

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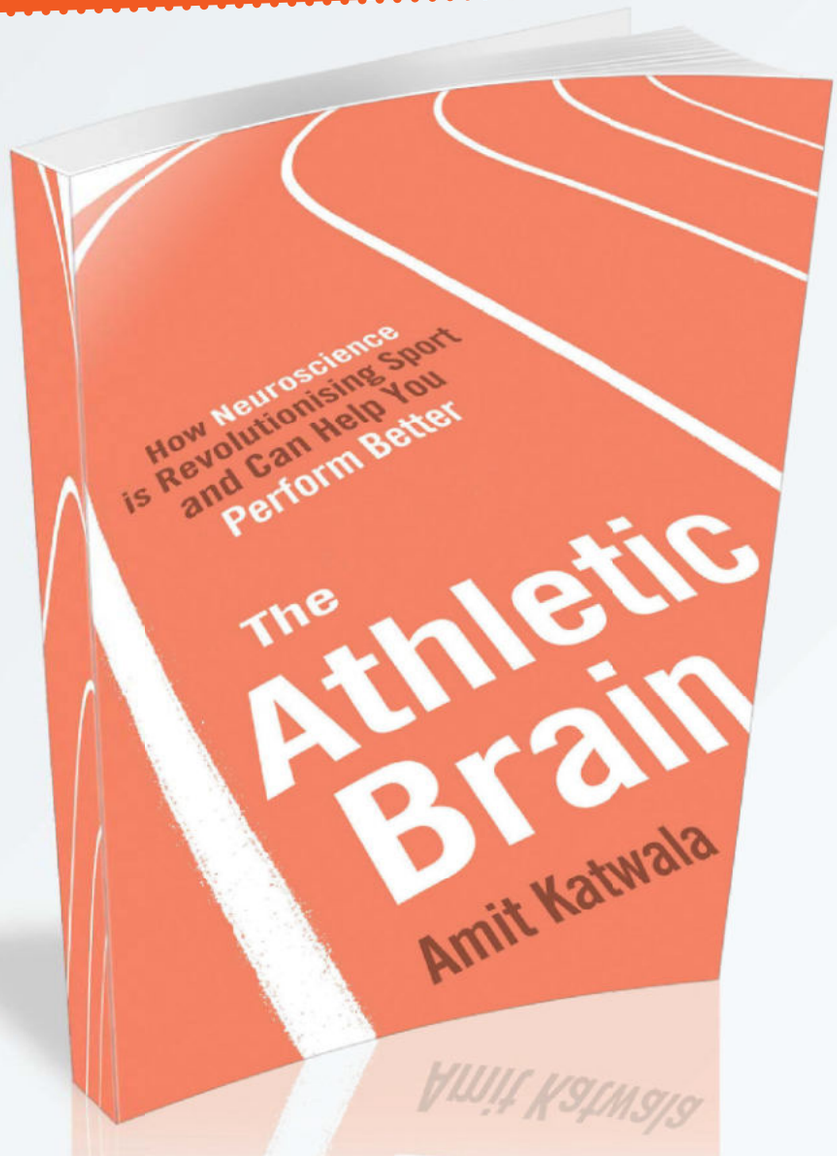
BOOK REVIEWS

The latest releases for curious minds

The Athletic Brain: How Neuroscience Is Revolutionising Sport

Improve your game by training your brain



- Author: **Amit Katwala**
- Publisher: **Simon & Schuster**
- Price: **£16.99 / $11.79**
- Release date: **Out now**

We all know that to be a top athlete you need incredible physical strength and self-discipline, but you may not realise that an immense amount of brainpower is vital too. Sports stars such as Cristiano Ronaldo and Roger Federer spend thousands of hours training their brains, not just their muscles, to help them anticipate their opponent's next move and perform with impeccable speed and accuracy.

In his first book, award-winning journalist Amit Katwala explains the science and technology behind the brain-training techniques used by some of the world's best-loved sporting heroes, providing an eye-opening insight into just how hard they work mentally, as well as physically. He then attempts to discover whether it's possible for amateur athletes to hack the system, using similar tools to improve their skills without having to practice for so many gruelling hours.

Although the niche subject of the book is aimed mainly at sport fans, particularly those who enjoy playing it as well as watching it, the well-written and captivating introduction is enough to draw in even those with a basic knowledge of sport. The author's fantastic powers of description then continue to engage the reader, perfectly setting the scene for the fascinating athlete anecdotes and interviews included in each chapter.

The science is explained well too, as Katwala manages to make the relatively complex topics of brain chemistry and vision easy to understand with the help of a few simple diagrams. From the very first page it's clear the author has done his research, with several interesting interviews and entertaining first hand-experiences of training techniques used to explain the scope of this new sporting revolution. Those without an enthusiasm for sport or neuroscience may struggle to persevere for 14 chapters, but several interesting 'try this at home' tips for improving your own brainpower help to break up the text. Overall the book provides a fascinating insight into the amazing science and technology pushing the boundaries of athletic performance, giving hope to all those wannabe medal and trophy holders looking for a fast-track to success.

★★★★☆

YOU MAY ALSO LIKE...

Faster, Higher, Stronger

Author: **Mark McClusky**
Publisher: **Avery**
Price: **£11.99 / $16**
Release date: **Out now**

A behind-the-scenes look at the science pushing the physical boundaries of a new generation of athletes, including breakthroughs in data, nutrition and training that can fast-track sporting success.

The Sports Gene

Author: **David Epstein**
Publisher: **Yellow Jersey**
Price: **£9.99 / $17**
Release date: **Out now**

This *New York Times* best-seller examines the nature versus nurture debate, discussing whether top athletes such as Usain Bolt were born to be great, or owe their success to obsessive training.

Choke

Author: **Sian Beilock**
Publisher: **Constable**
Price: **£8.99 / $16**
Release date: **Out now**

Psychologist Sian Beilock reveals the science of why athletes choke under pressure and what must happen in mind and body to overcome fear and achieve success. A fascinating read on the back of the Rio Olympics.

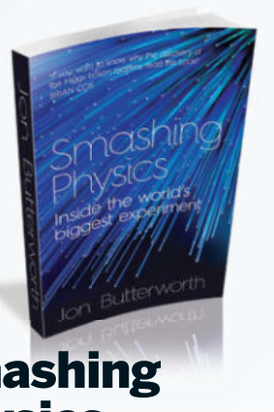
30-Second Newton

50 amazing theories from one man

- Author: **Brian Clegg**
- Publisher: **Ivy Press**
- Price: **£14.99 (approx $20)**
- Release date: **Out now**

There was a lot more to Newton than the incident involving the apple, as this collection of the man's best theories seeks to show. Each page offers a short passage focusing on one of these theories, explaining them in quick, easy-to-understand ways that will make you sound incredibly intelligent in front of your friends. There are other notes around the page, including short thoughts related to the theory, further reading, and imagery from the man himself and modern science. The book is really well put together, and the result is a collection of theories explained neatly, clearly and cleverly. It does a great service to Newton and is well worth a read.

★★★★★



Smashing Physics

Relive the search for the Higgs boson

- Author: **Jon Butterworth**
- Publisher: **Headline**
- Price: **£14.99 (approx $20)**
- Release date: **Out now**

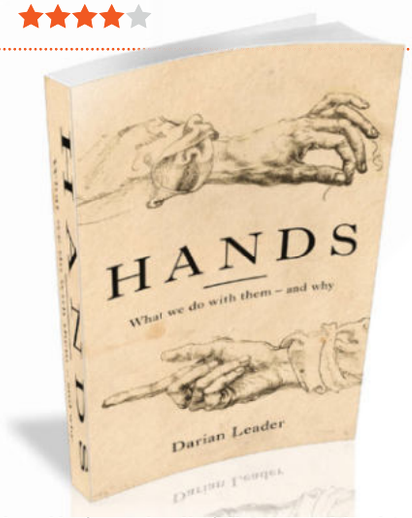
Explaining particle physics to someone who isn't... well, a particle physicist, is difficult. For this very reason, *Smashing Physics* can be a tough read at times, but thankfully Butterworth does a valiant job of explaining the most essential terms, while keeping things as accessible as possible. The result is a glimpse inside The Large Hadron Collider at CERN, and the 'big science' that is being conducted there. If you have even a passing interest in this project, the book is a brilliant read, packing stories, studies and scientific mistakes into a well-written account from one of the world's foremost physicists.

★★★★½

Hands: What We Do With Them – And Why

Studying the progress of humans through their hands

- Author: **Darian Leader**
- Publisher: **Penguin**
- Price: **£12.99 (approx $17)**
- Release date: **Out now**

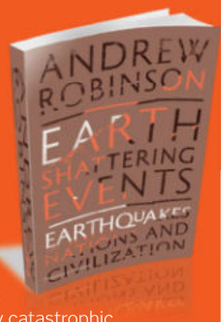


The expression 'twiddling your thumbs' tells more of a story than you would think. In *Hands*, Leader jumps from common phrases like this to pop culture, references to iPhones, and discussion about why humans are so obsessed with hands. In some cases, his arguments fall flat; like when he asks why action films often feature characters catching another by the hand before a deadly fall. In cases like this one, it's hard to ignore the fact that the hand is the most dextrous part of the human body. Thankfully, the book does have some interesting insight about the psychology surrounding mouths and hands, and how devices like smartphones will change the way the human body evolves.

★★★½☆

Earth-Shattering Events

How have people dealt with earthquakes throughout history?



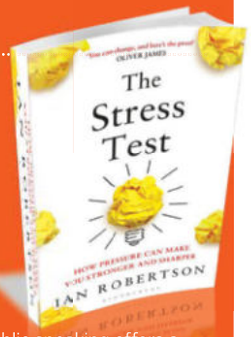
- Author: **Andrew Robinson**
- Publisher: **Thames & Hudson**
- Price: **£18.95 / $29.95**
- Release date: **Out now**

Earthquakes and tsunamis have devastated the world many times over the last few decades. And, as Robinson explains in *Earth-Shattering Events*, these huge acts of nature have actually changed the course of human history in more ways that you might realise. Robinson talks about ten particularly catastrophic examples, from Lisbon to Tokyo, and discusses their geographic, political and economical impact on the world. He makes big claims, including that the 2004 tsunami ended long-running wars in Indonesia and Sri Lanka, but everything is backed up with easy-to-understand data and studies.

★★★★½

The Stress Test

How pressure affects us for better or worse



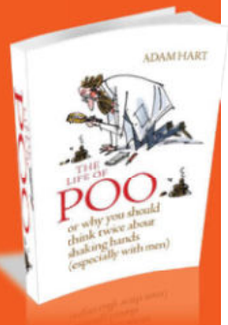
- Author: **Ian Robertson**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now**

Stress is an interesting topic. For some, public speaking offers a chance to shine, while for others the idea of speaking in front of people leaves them stumbling over words and panicking. In Robertson's book, he analyses the way people react to different levels of stress, and explains why people can flourish and achieve more with the right level of challenge and stress. There are some fairly standard strategies for getting more motivated, including sitting up straight and interrupting your 'automatic pilot', but there is also some real insight here. The discussion about 'approach' or 'withdrawal' is a core thread throughout the book, and Robertson is quick to emphasise that withdrawal can be constructive. It's a thought-provoking read.

★★★★½

The Life Of Poo

A myth-busting book that's flush with facts



- Author: **Adam Hart**
- Publisher: **Kyle Books**
- Price: **£12.99 (approx $17)**
- Release date: **Out now**

While the title of the book might raise a smile, *The Life of Poo* is concerned with some pretty serious topics. The main focus is on bacteria, and how it affects almost every part of our lives – you're likely to find it's a real eye-opener! Writing in an accessible and witty way, Hart does a fantastic job of packing in interesting and in-depth science, always explaining complex concepts in a way that's easy for anyone to understand. There are parts that will make you feel a little queasy, but trust us when we say that this book will teach you a lot – especially about washing your hands.

★★★★★

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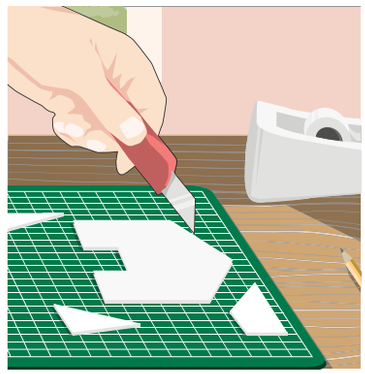
How to make a soap-powered boat

Propel a paper boat using nothing more than washing-up liquid!

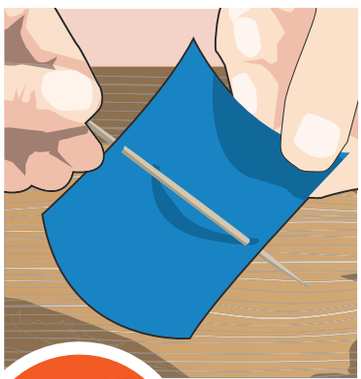
1 Prepare your sea

In order for this experiment to work, you need a calm, level surface of water for your boat to sail on. You can use a baking tray, a washing up bowl, or even your bath to create your sea, but you need to make sure that the water doesn't have any soap in it already, otherwise the boat won't sail!



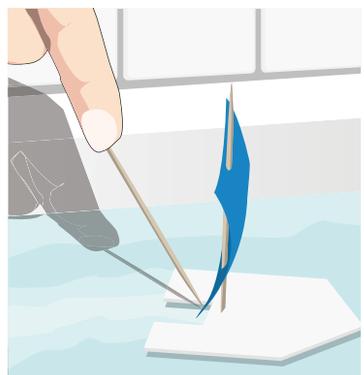
2 Cut out your boat

The main part of your boat should be made from a small piece of non-corrugated cardboard, or foam if you have any – either will work. Cut the foam or card into a house-like shape, like in the image, around five centimetres from top to bottom. You also need to cut a small notch into the back, about a centimetre wide. This is where the soap will go.



3 Add a sail

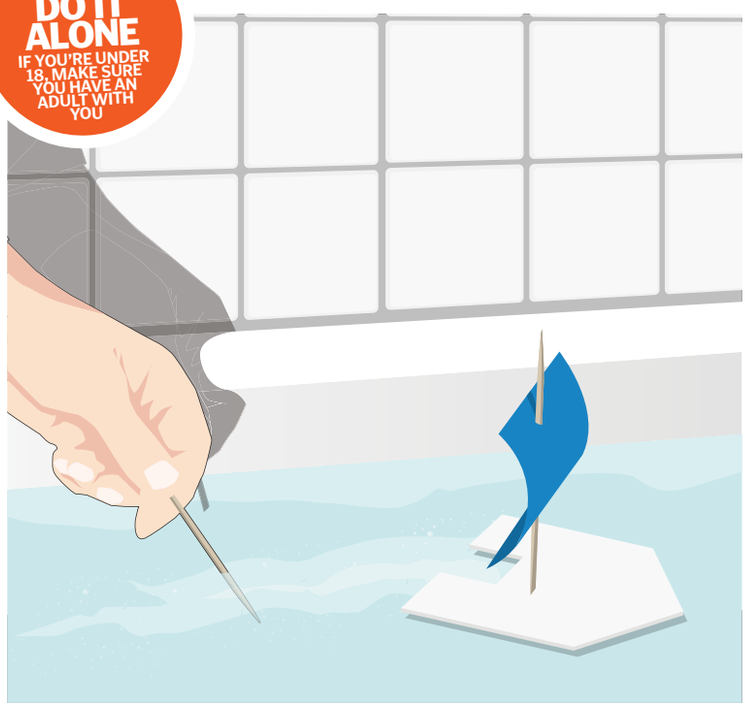
What's a boat without a sail? You can create one for your boat using a toothpick, a small piece of card and some Blu-tack. Cut the card into a rectangle, and then bend it slightly, before pushing the toothpick through it. Attach the sail to your boat with the Blu-tack. You could also personalise your creation by adding some decoration.



4 Prepare your boat

You can now get ready to set sail! Place your boat in the water, and if it doesn't balance well, try moving the sail to make sure it's flat. You need to put a couple of drops of washing-up liquid (or liquid hand soap) onto another toothpick, to make it easier to drop into the notch that you cut into the back of your boat earlier on.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



5 Set sail!

Use the toothpick to drip the washing up liquid into the notch on the boat, and it should start moving across your makeshift sea! The soap disrupts the arrangement of the water molecules – they are attracted to the soap molecules instead of just being attracted to each other. This reduces the surface tension of the water behind the boat. The boat is then pulled towards the area of higher surface tension in front of it, and starts to move forward.

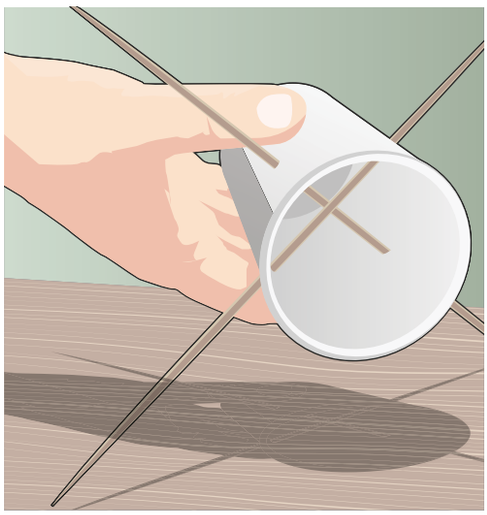
In summary...

Water molecules stick together because they are strongly attracted to each other, and this creates a strong but flexible 'skin' on the water's surface. This is called surface tension, and it's what allows the cardboard to float on the water. It is also what pulls the boat forward, as the soap reduces the surface tension behind the boat.

NEXT ISSUE
- MAKE AN ORB LEVITATE
- ROLL A FUNNEL UPHILL

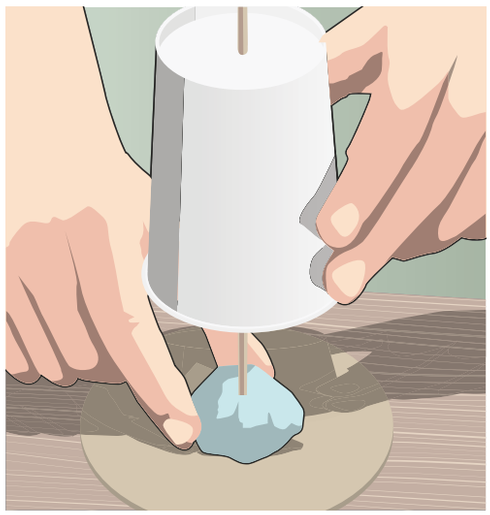
How to build a wind catcher

Create a wind-powered spinner to measure this force of nature



1 Create your windmill

Take a small paper cup and two wooden skewers. Stick a skewer through one side of the cup and out of the other, around halfway up. Then take a second skewer and do the same, but at a right angle to the first. Take a straw and use scissors to split one end of it into four flaps, each about two centimetres long. Fold these down, and fix the straw to the bottom of the paper cup.



2 Make the base

Next, you need a base. Take an old CD or DVD and stick a large blob of Blu-tack in the centre. Stick another skewer into this Blu-tack so that it is sticking up, straight into the air. Now take a second paper cup and hold it upside down over the skewer. Carefully push it down so that the skewer comes out through the bottom, and the cup covers up the blob of Blu-tack on the CD.

3 Start spinning!

Finally, take four more plastic cups and stick each one through one of the protruding ends of the skewers in your first cup. They should all face the same way so that they form a circle. Secure each one well with more Blu-tack, then stick a sticker onto the outside of one cup so you can count how many times it spins. Slide the straw over the skewer in the base of your spinner and you're ready to measure the wind!

Illustrations by Ed Crooks

In summary...

When the wind blows, it pushes against the mouth of one cup and the base of another. The force is greater on the cup's mouth, so the spinner turns. The wind enters the next cup, and turns the spinner further, and so on. This technology is used in huge wind turbines – the movement charges a generator to produce electricity!

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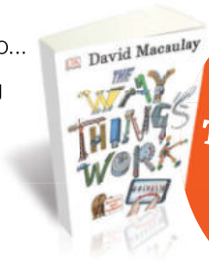


WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
THE WAY THINGS WORK NOW
This comprehensive guide reveals the wonders of modern technology in a unique and entertaining way.

Letter of the Month

Operation goldfish

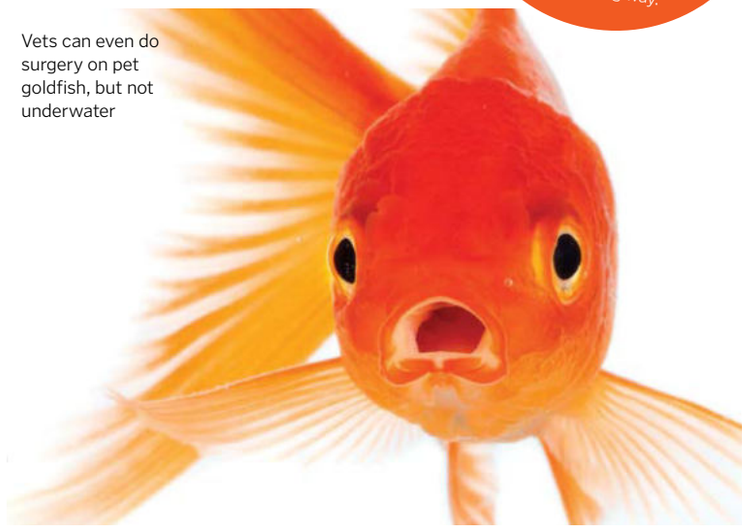
Dear **HIW,**
I love your magazine and find it really interesting! But my question is about marine biology. How do marine vets do operations on animals that live underwater, or do they not? If they don't is there a possible solution?
Megan Tough (age 11)

Vets will normally take animals that live underwater out of the water to do an operation. For a fish, vets put some anaesthetic into the water it's swimming in to send it to sleep before surgery.

The unconscious fish is then taken out of the water and oxygenated air is pumped into its mouth and over its gills so it can breath, a bit like having it wear a fish version of scuba gear.

The vet can then do the operation, before carefully returning the fish back to the water once it's over, but it might have to have another operation to have stitches removed later. Of course, not all aquatic creatures are fish.

Mammals that breathe air, like dolphins, can simply be taken out of the water to be operated on. Surprisingly, operations are not only done for expensive exotic fish in aquariums – some vets even operate on pet goldfish! We hope that clears things up, Megan!


Vets can even do surgery on pet goldfish, but not underwater

What's happening on... Twitter?

Make sure you follow us **@HowItWorksmag** for amazing facts, competitions and the latest in science & tech!

@DoctorCQuinn
@HowItWorksmag Moonlight is simply reflected sunlight. #DidYouKnow

@neiltyson
Eternal Geek Wisdom: In life and in the universe, may your signal be high, and your noise be low.

@solarimpulse
Solar Impulse goes around the world, completing its mission proving that zero-emissions is possible! #futureisclean

@usainbolt
Great feeling to be back on the track #TeamBolt #MissionRio

@NASA
#StarTrek creators started w/ science we know & stretched it in the show. How much is real? http://go.nasa.gov/2a5ZaeY

@ DarkPikachu27
@HowItWorksmag OMG #PokemonGO explained! I can't wait! XD

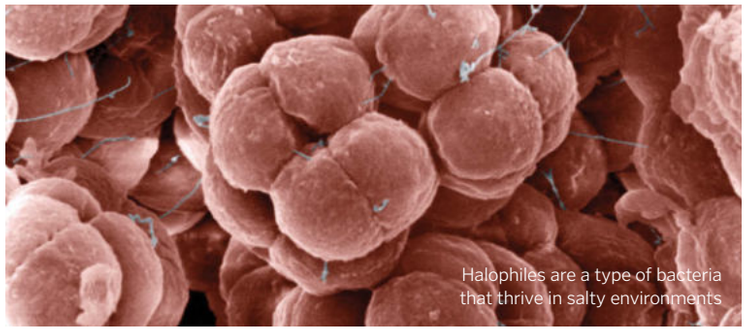
@mrspixelwife
@HowItWorksmag Perfect for my inquisitive son!

Steamy eyes?

Dear **HIW,**
My question is; when you walk into a humid atmosphere, why don't your eyes steam up, as would be the case with spectacles?
Ted – a young 71 subscriber

Warm, humid air contains a lot of evaporated water vapour. It steams up your spectacles because the cold temperature of the lenses causes the water in the atmosphere to condense. This turns it from a gas back into a liquid that forms tiny droplets of water, which cloud your lenses. Unlike spectacles, your eyes are always quite warm and so they wouldn't be cold enough for water vapour in the air to condense on them normally. In any case, eyes are already wet, and a few extra tiny droplets of water would be barely noticeable.


Spectacles can get steamed up in humid atmospheres as water vapour condenses


Halophiles are a type of bacteria that thrive in salty environments

Salted or sweet bacteria?

Dear **HIW,**
I am an avid reader of your magazine and I love the diversity of the articles and topics. My question is – which dries out bacteria quicker, sugar or salt?
Daniel Stott (age 11)

High concentrations of sugar and salt cause bacteria to dehydrate through a process called osmosis that pushes water out of bacterial cells to make them as salty or sugary as the environment they are in. There's no easy answer for whether salt or sugar is most effective, as it depends largely on the type of bacteria. While salt may kill many bacteria, some classes of bacteria, called halophiles, actually need highly salty conditions to live.

Where does lightning strike?

Dear **HIW,**
I love your magazines and I wanted to ask a question. Recently there have been a few storms in the UK and I was watching lightning maps. How can you detect and map lightning?
Nick Richards

A lightning strike causes a pulse of very low frequency radio waves, called a sferic, which can be detected by radio sensors many hundreds of miles away. These can show that a lightning strike has happened, but to map *where* it's happened needs a network of these sensors placed around the world. All the different sensors detect the same lightning strike but at slightly different times depending on their distance from it. Meteorologists can then compare the results of the different sensors to triangulate where individual strikes happen and plot them on a map.


Comparing the results of different lightning detectors allows meteorologists to map lightning strikes

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

3,000 The number of snake species in the world

1932 THE YEAR A PHOTO FINISH CAMERA WAS FIRST USED AT THE OLYMPICS IN LOS ANGELES

9% The proportion of schools in the UK that have a tablet computer for each pupil

A LIGHTNING STRIKE IS FIVE TIMES HOTTER THAN THE SUN'S SURFACE

1,600 THE ESTIMATED NUMBER OF MAJOR VOLCANOES OR VOLCANIC FEATURES ON VENUS

20% of Earth's fresh water is located in the Amazon River basin

OVER HALF YOUR BODY'S BONES ARE IN YOUR HANDS AND FEET

240km/h THE SPEED OF THE FASTEST ROLLER COASTER IN THE WORLD, FORMULA ROSSA IN ABU DHABI

17.8cm THE DIAMETER OF THE LARGEST RECORDED HAILSTONE

IF YOU FEED A HAMBURGER TO A VENUS FLYTRAP THE PROTEIN AND FAT WILL KILL THE PLANT

8mn litres THE ESTIMATED AMOUNT OF BEER DRUNK EVERY YEAR AT OKTOBERFEST IN MUNICH, GERMANY

200mn THE NUMBER OF PASSENGERS EXPECTED TO USE CROSSRAIL EACH YEAR ONCE SERVICES BEGIN IN 2018

320km/h+ The speed of winds that tornadoes are able to produce

400km/h THE SPEED AT WHICH SOME NERVE IMPULSES RACE AROUND THE BODY

1.3 GRAMS The amount of gold per 1,000 tons of other material in Earth's crust

539,000m² The amount of space Tesla's Gigafactory will cover when completed in 2020

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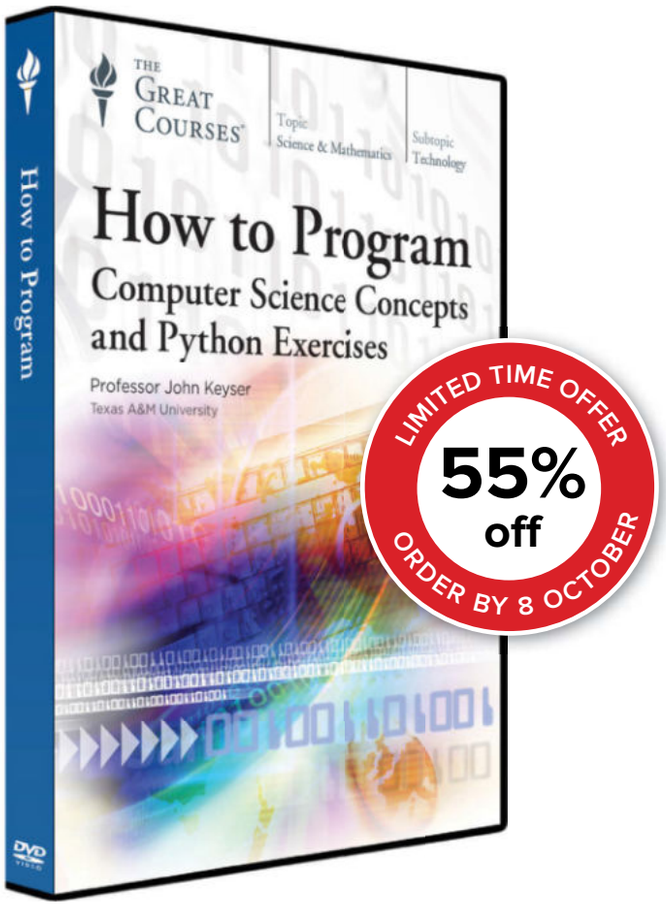

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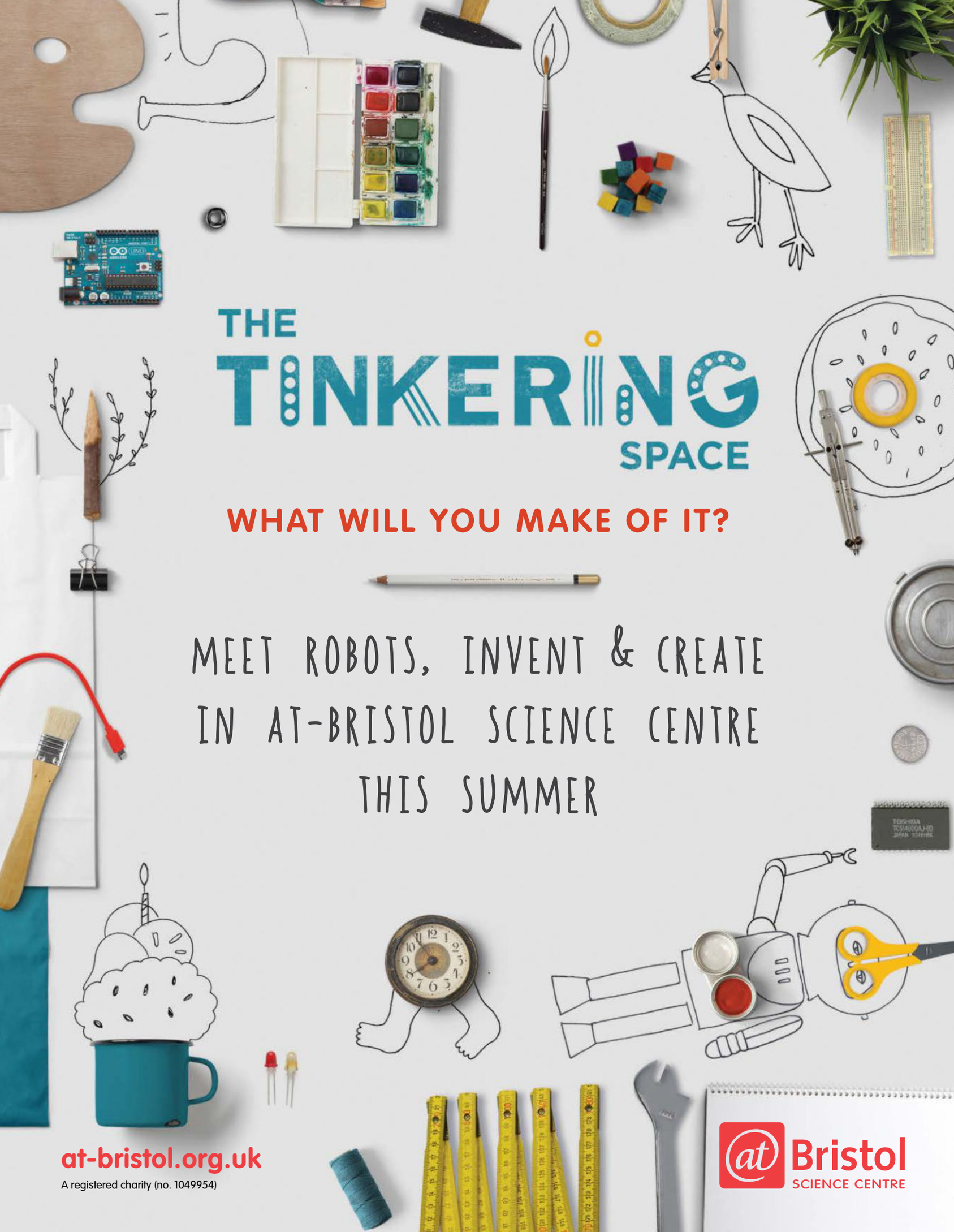
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